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STEEL EQUIPMENT DIVISION
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GRANITE CITY STEEL COMPANY

Steel Pioneers in the West

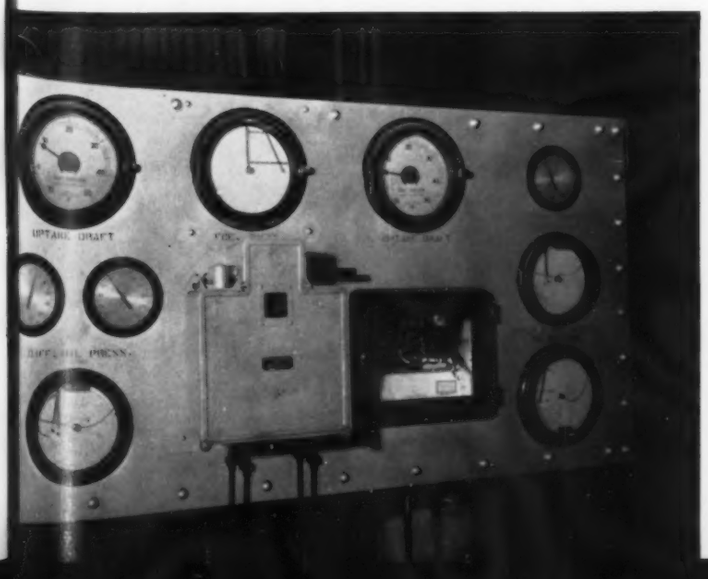
By T. J. ESS *and* J. D. KELLY *with personnel photographs by* J. R. SCOTT

▲ WITH a history dating back approximately 90 years, the Granite City Steel Company, at Granite City, Illinois, offers an interesting picture of gradual development from the initial small stamping shop of 1850 to the present mill embodying the modern methods of steel production. This development proceeded through the various steps of stamping, enameling, sheet iron production, tinning and galvanizing, steel manufacture, and strip production, in a constant panorama of expansion and improvement under the guidance of the Niedringhaus family, the third generation of which is now represented by Hayward Niedringhaus, president of the company.

To insure a supply of sheet iron for the original St. Louis Stamping Company, the Granite Iron Rolling Mills were built in St. Louis in 1878. This plant was designed for the production of wrought iron, with subsequent reduction to sheet form. The installation of tin mills and galvanizing equipment naturally followed. Increasing space requirements finally necessitated the construction of a plant in Illinois, across the Mississippi River, at what is now Granite City. This new Granite City Steel Company consisted of open hearth furnaces, blooming mill, sheet bar mill, and plate mill. Eventually consolidated with the other two enterprises under the National Enameling and Stamping Company, the Granite City Steel Company was finally incorporated as a separate entity in 1927. Meanwhile, open hearth capacity was increased and tin mills installed. The Granite Iron Rolling Mills were supplanted in 1923 by a sheet mill installation in Granite City. In 1936 a 90 in. hot strip mill was built, and cold reduction mills have been added. Various improvements have also been made in auxiliary departments to keep pace with the progress of the producing departments.

The plant occupies an area of more than 120 acres. Coal is procured from the nearby fields of southern Illinois, natural gas is available from a trunk pipe line from the fields of Louisiana, and water is procured from deep wells. The company, with an annual ingot capacity of 400,000 gross tons, produces basic open hearth steel in ingot, slab, billet, plate, sheet bar, sheet and strip forms. A wide variety of sheet products are available, including electrical, galvanized, tin plate, terne plate,

This open hearth panel carries a furnace pressure controller, in addition to instruments showing various operating conditions of the furnace.



In addition to the conventional soaking pits shown in the background, a block of modern one-way pits makes up heating facilities for the blooming mill.

enameling iron, special finish sheets, and formed roofing and siding. Stainless-clad material is also produced.

STEEL PRODUCTION

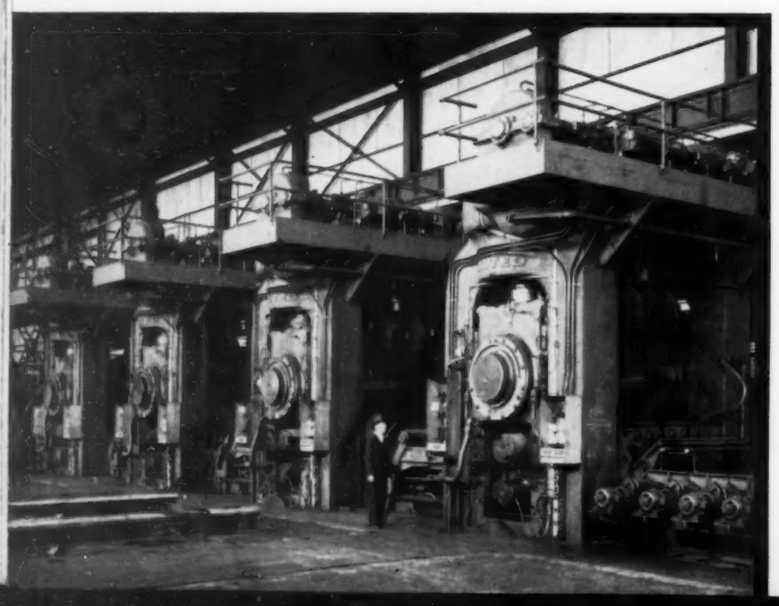
Steel production is centered in ten basic open hearth furnaces, with hearth dimensions 23 ft. long x 12 ft. wide and rated at 60 gross tons each. The furnace charges are cold, although facilities are installed for handling hot metal, which was formerly received from a nearby independent blast furnace plant. The furnaces operate on a 12 degree Baume fuel oil from a circulating oil system. Six oil tanks afford a total storage capacity of 660,000 gal. Oil is supplied to the system at 180 lb. per sq. in. pressure, and is heated to approximately 220 degrees F. temperature at the burner.

Two 80 ton ladle cranes handle the ladles in the pouring pit, and the steel may be poured at either of two pouring platforms. Ingot sizes vary widely according to the ultimate disposal of the product, and range from 5,000 lb. to 15,000 lb. in weight, and from 20 in. to 54 in. width x 18½ in. thickness x 60 in. high. The hot ingot moulds are sprayed with tar before pouring.

Soaking pit facilities include one block of four one-way fired holes, three regenerative blocks of two holes each, and three regenerative blocks of four holes each, all burning natural gas with an average consumption of 1,700,000 Btu. per ton. The pits are located in a single row at right angles to the mill lines, and are served by two pit cranes. Ingots from the pits may proceed to the blooming and bar mill, or to the slabbing mill, which parallel each other about 65 ft. apart.

The blooming mill is a 35 in. two-high reversing stand, driven by a 36 in. x 48 in. twin steam engine. It is followed at a distance of about 300 ft. by the bar mill, a 24 in. unit consisting of a three-high stand and a two-high stand placed side by side and driven by a single motor of 2000 hp. A cooling bed, 180 ft. x 300 ft., transfers the bars to a parallel shear table.

The finishing train of the hot mill is composed of a scale-breaker and four stands, and is fed from a three-high reversing rougher.



J. H. VOHR

General Superintendent

Ingots are broken down into slabs in a two-high 30 in. x 100 in. reversing mill, driven by a 36 in. x 48 in. twin non-condensing steam engine operating on 160 lb. pressure. This mill was previously the roughing stand for the former plate mill. A turn-table was installed in order that ingots might be spread to obtain wide slabs. Following this stand at a distance of about 30 ft. is a reversible vertical slab edging mill, driven by a 1000 hp., 300–600 rpm. d-c. motor. Approximately 38 ft. farther along the mill line is a 900-ton, 103 in. x 5 in. up-cut slab shear, steam-hydraulically operated. From this shear, slabs may proceed on a direct line through the wide strip mill, or may be moved at right angles over an inclined chain conveyor about 80 ft. long to the slab storage building. The latter course is generally followed, and slabs are conditioned by the manual scarfing process in order to remove surface defects.

Slabs range 21¾–86½ in. in width, 3–6½ in. in thickness, 60–85 in. in length, and 1800–10,200 lb. in weight, averaging about 30 in. x 4½ in. x 70 in., and 2700 lb.

HOT STRIP MILL

A single continuous slab-heating furnace is installed, with space provided for a second furnace if desired in the future. The furnace is located in the conventional manner, at 90 degrees with the mill line, with the charging end in the slab yard and the discharge end adjacent to the mill approach table. Slabs are moved to the furnace by overhead cranes, and deposited on a hydraulically operated elevator feeder. A double head rack-type pusher, driven by a 100 hp. d-c. motor, moves slabs into the furnace, which is rated at 50 gross tons per hr. Hearth dimensions are 70 ft. x 18 ft., with 16 ft. of the length being devoted to soaking zone. The flat suspended roof of the furnace is covered with 4 in. of insulation, while 6 in. of insulation is applied to the side

The hot mill runout table, about 200 ft. long, is driven by individual motors rated at 3–1 hp., 440–147 volts, 60–20 cycles, 3 phase.

walls and 8 in. to the hearth. Natural gas is introduced through the usual triple-zoned firing arrangement, with six luminous flame type burners in the top heating zone, five in the bottom heating zone, and six in the soaking zone, thus providing a total burner capacity of about 130,000,000 Btu. per hour. Fuel consumption averages about 2,400,000 Btu. per ton. Air for combustion is preheated in a refractory tile recuperator, and furnace pressure is automatically controlled.

Under the action of the furnace pushers, the hot slab is discharged from the furnace and proceeds to the hot mill, which consists of a two-high roughing scalebreaker, a three-high roughing mill with integral vertical edger, a two-high finishing scalebreaker, and four four-high finishing stands.

The roughing scalebreaker is a two-high 30 in. x 100 in. unit, driven by a 700 hp., 505 rpm., 6600 volt wound rotor induction motor. Hydraulic sprays on the exit side of this stand remove furnace scale from the slab, which proceeds down the tables to the roughing mill, 47 ft. 6 in. distant. This mill is a three-high 22 in. and 34 in. x 100 in. unit formerly used as a plate mill, and is driven by a 3000 hp., 237 rpm., 2300 volt wound rotor induction motor. An integral edger, driven through gearing by the main drive motor, has been provided.

Following the rougher, a delay table 125 ft. long leads to the finishing train, the first unit of which is a two-high 27 in. x 90 in. stand, driven by a 350 hp., 450–900 rpm., 600 volt d-c. motor. Following this are four four-high 26½ in. and 53 in. x 90 in. finishing stands, all driven by 600 volt d-c. motors, the first three of 3500 hp., 175–350 rpm., and the last, 2500 hp., 225–450 rpm. These stands are spaced on 20 ft. centers. Space is available for a fifth finishing stand if it should be desired.

Brass bearings are used on the roughing scalebreaker, while composition bearings, water lubricated, are employed on the three-high rougher and the finishing scale breaker. The four-high finishers operate with roller bearings on the work rolls and oil-film bearings on the back-up rolls. Roller bearings are also applied to all pinion stands and gear sets.

An automatic pressure grease system lubricates the roller bearings, while a circulating oil system serves the oil film bearings.

Gear ratios, roll speeds and strip speed in the hot mill are as follows:

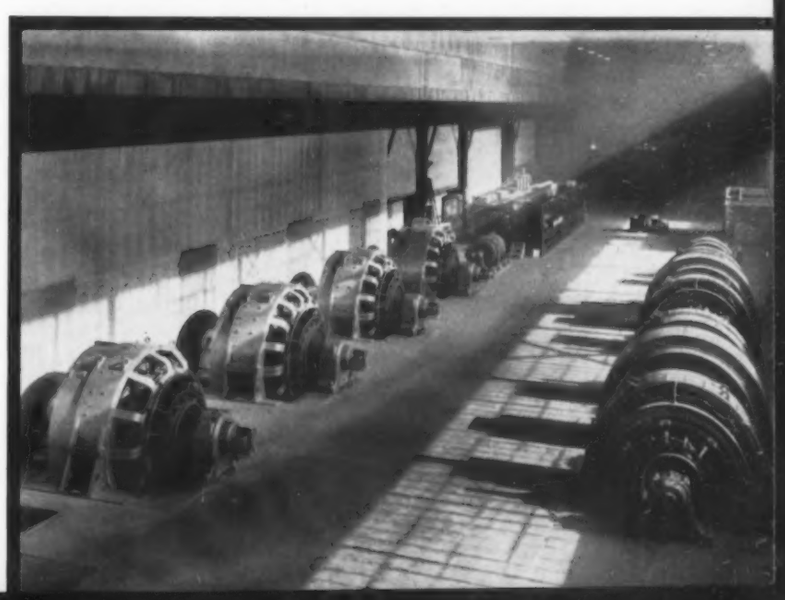
	Motor rpm.	Gear ratio	Roll rpm.	Strip speed, ft. per min.
Roughing scalebreaker	505	35.7	13.8	108.5
Three-high rougher	237	4.5	52.55	468
Finishing scaelbreaker	450/900	22.75	19.8/39.6	138/275
No. 1 finisher	175/350	5.2	33.6/67.3	234/468
No. 2 finisher	175/350	3.58	48.8/97.6	339/678
No. 3 finisher	175/350	2.72	64.3/128.6	446/892
No. 4 finisher	225/450	2.72	82.7/165.4	575/1150

Screws on the roughing scalebreaker are driven by a single 60 hp. d-c. motor, while a 75 hp. motor is used on the three-high rougher. Two 35 hp. motors are used on each stand of the finishing train, driving the screw-downs through magnetic clutches.

The removal of scale from the surface of the steel is effected by hydraulic sprays located at the two-high slabbing mill, the roughing scalebreaker, and the finishing scalebreaker. Water is supplied to these sprays from two five-stage 5 in. x 4 in. centrifugal pumps, each rated at 600 gal. per min. at 1000 lb. per sq. in. pressure, and each driven by a 500 hp., 2300 volt, 3570 rpm. induction motor. Spray valves are operated by solenoid control, and an accumulator in the system aids in reducing hydraulic shock due to the operation of the valves. Steam jet blowers are also installed in front of the roughing scalebreaker and on both sides of the roughing unit.

To take up any slack occurring in the strip as it passes through the finishing train, three loopers are installed, one between each successive pair of stands. They are

General view of hot mill motor room, showing main roll drive motors and finishing train motor-generator sets.



B. B. JOHNSTON

Assistant General Superintendent

driven by 32 volt torque motors of 140 lb.-ft. capacity, controlled from the speed operator's pulpit by timed acceleration magnetic control. Power is derived from a 15 kw., 32 volt generator driven by a 20 hp., 440 volt, 1750 rpm. induction motor.

Hot mill product, on an average, consists of about 39 per cent breakdowns for re-rolling on the hot sheet mills, 10 per cent to breakdowns for re-rolling on hot tin mills, 35 per cent to hot rolled finished material, and 16 per cent to cold rolled material. Due to the flexibility of the mill layout, a wide variation in reduction practice is possible. Slab thickness may be reduced as low as 1¾ in. in the slabbing mill if so desired. Plates, which form about 20 per cent of the total production, are rolled in thicknesses from 3/16 in. up, being rolled direct on the slabbing mill for very heavy material, taken off at the three-high rougher for intermediate thickness, or passed on through the finishers for the lighter material. In the rolling of strip, the thickness is reduced down to .4–.5 in. in the three-high rougher. In the finishing train, reductions range 30–50 per cent, 25–40 per cent, 20–25 per cent, and 8–10 per cent, respectively, in the four stands.

Leaving the finishing train, where strip temperature is measured by a radiation pyrometer, the strip proceeds down the runout table for a distance of 200 ft. to a three-roll up-coiler. Coils of 22 in. inside diameter and up to 38 in. outside diameter are formed in all widths up to the maximum produced on the mill. The coiler is driven by a 100 hp., 230 volt, 500–1250 rpm. shunt motor. A conveyor then moves the coils from the coiler, over a scale, and into the coil storage.

Runout table rolls are driven by 109 individual 3 hp., 147–440 volt, 20–60 cycle, 550–1700 rpm. gear motors, with a 3:1 ratio, the motors receiving power from two variable frequency sets, one of 375 kw., and one of 62.5 kw. capacity. A 50 kw. dynamic braking set is also provided.

Closely following the coiler in the runout line is a rotary flying shear, capable of cutting lengths of 96–240 in., and driven by a 100 hp., 250 volt, 300–1050 rpm., d-c. motor under timed magnetic control. Cut lengths from this shear pass through pinch rolls and on to a piler.

Heavy stock may be moved from the runout table to a parallel cooling table over a 54 ft. chain type transfer located between the finishing train and the coiler. The cooling table is about 460 ft. long, and contains a 100 in. roller leveler and a 108 in. parting shear.

E. H. WERNER

Chief Engineer

E. H. WAHLERT

Assistant Chief Engineer

A 192 in. trimming shear is placed at the end of this table.

The layout and equipment of this mill is another example of effective design for attaining flexibility of operation and diversity of product. With limited capacity, it is not desirable to incur the heavy investment of the conventional large strip mill, but rather to compromise between capacity and investment cost. This trend, so necessary for the smaller producers, has been actively stimulated by the economic history of the past decade, and the installation under discussion represents an excellent solution to the problem.

Two four-high reversing mills, 16¾ in. and 52 in. x 48 in., reduce hot rolled strip .08–.10 in. thick down to gauges as low as .0092 in.

J. W. MILLS

Superintendent of Open Hearths

MOTOR ROOM

Paralleling the hot mill, and lying between the mill building and the slab building, is the hot mill motor room, 310 ft. long x 54 ft. wide, in which are housed the main drive motors, together with their switch gear,

Entry side of 18½ in. and 52 in. x 48 in. temper pass mill, showing drag generators in the foreground. The mill attains a maximum delivery speed of 2420 ft. per min.

H. B. BRUSH

Superintendent of Slabbing Mill and Hot Strip Mill

motor-generator sets, etc. The rougher motor is controlled through secondary resistance, using a liquid slip regulator, while the finishing train is under a Ward-Leonard system plus field control. Power is furnished to the finishing drives from two dual motor generator sets, each composed of two 2500 kw., 600 volt d-c. generators driven by a 6150 kva., 90 per cent power factor, 6600 volt, 514 rpm. synchronous motor. A 200 kw. 250 volt exciter set is also provided. Auxiliary d-c. power originates from a 1000 kw., 250 volt generator driven by a 1430 hp., 6600 volt, 720 rpm. synchronous motor.

Electrical machinery is cooled by recirculated air in a closed system complete with fans, filters and coolers.

Rotating electrical machinery in the strip mill totals somewhat as follows:

Motors, hot mill	35,780 hp.
Generators, hot mill	15,400 hp.
Total, hot mill	51,180 hp.
Motors, cold mill and finishing	13,190 hp.
Generators, cold mill and finishing	6,430 hp.
Total, cold mill	19,620 hp.
Grand total	70,800 hp.

The connected power load of the hot and cold strip mill is as follows:

	kva.
Roughing scalebreaker,	
700 hp. x .746, 80 per cent power factor	653
Three-high rougher,	
3000 hp. x .746, 80 per cent power factor	2,800
Finishing train motor-generator sets,	
2 x 6150 kva	12,300
Auxiliary motor generator set,	
1430 hp. x .746, 90 per cent power factor	1,185
Descaling pumps,	
2 x 500 hp. x .746, 80 per cent power factor	932
Circulating pumps,	
2 x 150 hp. x .746, 80 per cent power factor	280
Cold mill motor generator sets,	
2 x 1750 x .746, 80 per cent power factor	3,260
2500 x .746, 90 per cent power factor	2,075
Transformer banks,	
Hot mill auxiliary power	1,000
Hot mill light	225
Hot mill light	100
Cold mill auxiliary power	450
Cold mill auxiliary power	225
Cold mill light	150
Total basic connected load	25,635

FINISHING PROCESSES

Located at the runout end of the hot mill building are various units of equipment used for processing hot finished material. Here is a skin pass line, used to resurface and straighten sheets from the hot strip flying shear. The mill is a two-high 30 in. x 90 in. mill driven by a 500 hp., 2200 volt, 350 rpm. motor. A gear reduction of 9.7:1 gives a roll speed of 36.1 rpm., or 283.5 ft. per min. The mill handles sheets in lengths of 8–20 ft., from No. 14 gauge up to $\frac{3}{16}$ in. thick. A $\frac{3}{16}$ in. slitting and shearing line is also installed here, and is used for side trimming and cutting to length. This line is composed of a side trimmer and slitter, roller leveler, up-cut shear, gauge table, and pinch rolls, and operates at a speed of 150 ft. per min. Material comes to this unit in widths of 24–84 in., and lengths of 8–20 ft.

N. W. TUCKER

Superintendent of Cold Strip Mill

Widths may be slit down to 9 in., and lengths cut to lengths of 1 to 20 ft.

Material to be cold reduced or re-rolled on sheet or tin mills is transferred from the hot strip mill in railroad cars. Coils intended for cold reduction are pickled in a vertical mast four-arm rotary coil pickler. Mandrels upon which the loosely wound coils hang are rotated by chains driven by motors mounted on top of the pickler arms, while the solution is circulated through the loose wraps of the coils by a motor-driven propeller, with the flow parallel to the axis of rotation of the coils. Coils are prepared for this pickler by being passed through a loose-coiling line, consisting of an up-ender, a conveyor, a shear, an unwinding mandrel, and an up-coiler and back-spinner. Coils range from No. 10 to No. 14 gauge, 22–46 in. in width, and about 400 ft. long. The unit operates at a speed of 200 ft. per min.

In order to attain greater economy in cold rolling, a welding line has been provided, in which three hot-rolled, pickled coils are welded into one continuous coil. Strip is fed from the uncoiler through a leveler and into a retractable open throat up-cut shear. After adjacent ends of leading and following strips have been sheared, the shearing unit is moved back from its position, and pulls the welding head into place. With the strip ends firmly held by hydraulically operated clamps, the welding is accomplished by automatically controlled multiple tip oxy-acetylene blow pipes. Welding heat is automatically controlled by photo-electric cell so as to give the correct penetration from top to bottom. After the weld is completed, the welding heads separate and the joined ends are run into side clippers, where the unmatched ends are clipped out. The joined coils are then run through back tension rolls and on to the recoiler mandrel. The weld is slightly skewed from the right angle position with reference to strip movement, the skewed weld reducing shock as the weld passes through the cold mill.

DAWSON PUGH

Superintendent of Hot Mills

COLD REDUCTION

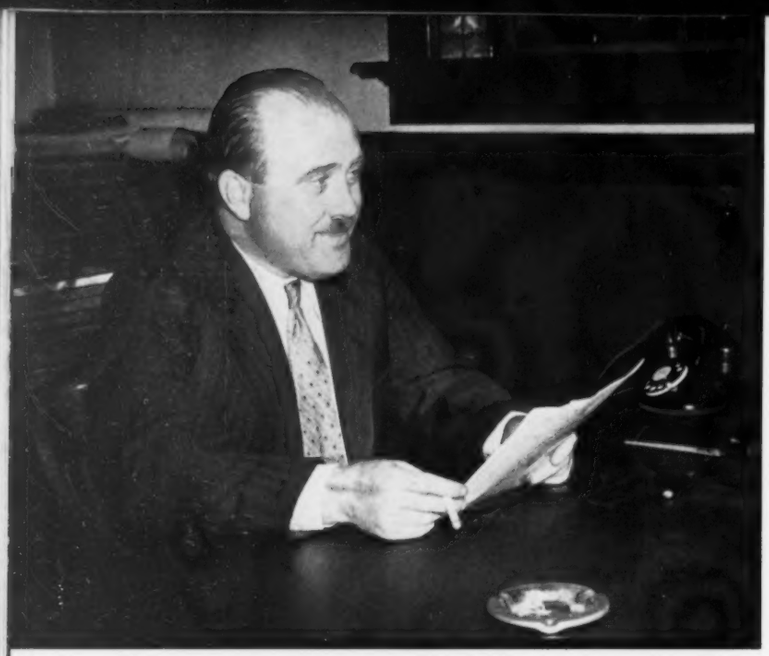
Cold reduction facilities are composed of two similar four-high reversing mills, 16¾ in. and 52 in. x 48 in. Both of these units are equipped with roller bearings on the work rolls and oil film bearings on the backup rolls. The earlier mill is driven by a 1250 hp., 600 volt, 350–585 rpm. motor. A gear reduction of 2.517:1 gives a roll speed of 139–232 rpm., or 610–1020 ft. per min. The reels of this unit are each driven by a 600 hp., 600 volt, 400–900 rpm. motor through a gear reducer of 6.714:1 ratio. The main motor and reel drives receive power from a motor generator set composed of one 1000 kw., 600 volt generator, one 300 kw., 350 volt drag generator, and one 30 kw., 250 volt generator, all driven by a 1750 hp., 6600 volt, 720 rpm. synchronous motor.

The newer mill is driven by a 1750 hp., 600 volt, 300–640 rpm. motor. The gear ratio in this unit is also 2.517:1, giving a roll speed of 119–254 rpm., or 520–1110 ft. per min. Two 800 hp., 600 volt, 400–900 rpm. motors drive the reels for this mill. Mill and reel motors are powered from a motor generator set consisting of one 1500 kw., 600 volt generator, one 600 kw., 450 volt generator and one 50 kw., 250 volt generator, driven by a 2500 hp., 6600 volt, 514 rpm. synchronous motor.

These units reduce strip in widths of 22–44½ in. from .08–.10 in. down to gauges as low as .0092 in. Total reduction in cold rolling averages about 75 per cent. Both mills are equipped with automatic gaugers, roll pressure indicators, and strip tension indicators.

B. F. BUTLER

Superintendent of Tin House



F. G. WHITE, *Chief,* Department of Metallurgy and Inspection

A. C. STOEVER, *Power and Electrical Engineer*

N. P. VEEDER, *Assistant to Chief*
Department of Metallurgy and Inspection

After cold rolling, the strip may be passed through a scrubbing line, consisting of a reel rack, a scrubber, a dryer, tension rolls, and a collapsible reel. This unit operates at a speed of 300 ft. per min., and, besides scrubbing the strip, produces a tightly wound coil for annealing. At this stage in the processing, the strip may range from No. 20 to No. 38 gauge, and the coils weigh 6000–12,000 lb., depending on width and gauge.

Box annealing equipment offers means of annealing in either sheet form or coil form. Twelve in-and-out furnaces, arranged in six double units, handle the flat annealing. They are charged by electrically operated machines, and are fired with natural gas with a fuel consumption averaging about 2,250,000 Btu. per ton. For coil annealing, three radiant tube portable annealing covers, each provided with three bases, have been installed recently. These covers use natural gas, with a consumption averaging about 1,500,000 Btu. per ton. Annealing cycles show 24–48 hr. heating period, and 25–26 hr. soaking period.

Processing of the coils is completed by temper rolling, which is effected in a recently installed temper mill. This unit is a four-high, 18½ in. and 52 in. x 48 in. mill, driven directly by a 500 hp., 600 volt, 200–500 rpm. motor, giving a delivery speed of 970–2420 ft. per min. Tension rolls are driven by a motor duplicating the main drive, while the reel is driven by a 150 hp., 250 volt, 400–1200 rpm. motor. Two 55 kw., 250 volt drag generators provide entering tension. The motor generator set for this mill is made up of one 1000 kw., 600 volt generator, one 125 kw., 250 volt generator, and one 40 kw., 250 volt generator, all driven by a 1750 hp., 6600 volt, 720 rpm. synchronous motor.

In the cold mill departments, the various miscellaneous shearing equipment includes the following:

One line for side trimming, slitting and recoiling, consisting of reel rack, side trimmer, drag table and reel; for full length coils of No. 16–38 gauge, 12–44 in. wide; speed, 600 ft. per min.

Two lines for side trimming, cutting to length, and classifying, consisting of uncoiler, side trimmer, flying shear, classifier with table and belt, and piler; for full length coils of No. 20–38 gauge, 22–44 in. wide; cut lengths of 12–54 in. and 15–144 in., respectively; speed, 300 ft. per min.

TIN AND SHEET MILLS

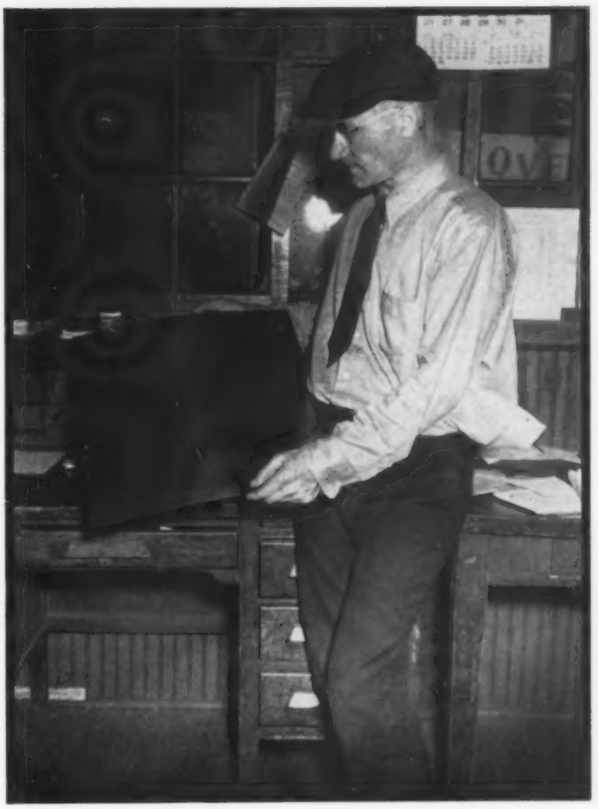
Hot rolled strip which is to be re-rolled in the tin mills is brought to a shearing line located in the bar storage shed. This unit takes 400 ft. coils in 22–50 in. widths, .075–.120 in. thick, and cuts lengths of 26–120 in., which are then doubled. The line operates at a speed of 175 ft. per min., and consists of an uncoiling mandrel, three-roll uncoiler, leveler looping table, shear, gauge table, conveyor, pinch rolls, and doubler. Breakdowns from this unit may be rolled on a train of hot mills consisting of seven conventional stands, two of which are equipped with mechanized feeding and catching equipment. The mills are driven by a 30 in. x 56 in. x 60 in., 30 rpm. steam engine. Material is heated for these mills in continuous walking beam furnaces fired with natural gas, with a fuel consumption averaging about 5,400,000 Btu. per ton. A wide heavy gauge jobbing mill is also installed in this department.

Material from the tin mills is pickled in two vertical plunger four-arm batch picklers, and subsequently box annealed in the furnaces previously mentioned. Cold rolling facilities consist of four single two-high mills and two tandem lines, each of three two-high stands joined by rubber belt conveyors. These mills are driven by a 28 in. x 48 in. steam engine.

The plate next passes through a three-arm white pickler and on to the tinhouse, where eight tinning lines are installed. The tin pots are heated with natural gas, with a consumption averaging about 740,000 Btu. per ton.

At the company's North Plant is a sheet mill, built in 1923, which is also now used principally for re-rolling breakdowns from the hot strip mill. For this purpose four two-high mill stands are used, driven by a 2000 hp., 240 rpm. induction motor. Breakdowns are heated for these mills in two walking beam furnaces, and automatic feeders and catchers are provided on the mills.

Sheets are pickled in a vertical plunger batch type pickler, followed by box annealing. Eight in-and-out furnaces are installed, in addition to four radiant tube portable annealing covers. Under construction are two electric bell type annealing furnaces, which are to be used in the processing of silicon material for electrical uses. Cold rolling is effected in two conventional two-high mills driven by a 150 hp. motor. A rocker-type pickler precedes the galvanizing operation, which is carried out in four galvanizing machines, two of 42 in. width and two of 54 in. width.



F. R. KNIPPING

Superintendent of Finishing Departments

•

J. J. BRADEN

Superintendent of North Plant

C. E. ARMFIELD

Superintendent of Galvanizing Departments

POWER SUPPLY

All electric power used in the plant is generated in the company's own power plant. This department is composed of two 3000 kw. mixed pressure turbo-generators and two 7500 kw. automatic extracting turbo-generators. The two 7500 kw. units take steam at 400 lb. pressure, and extract automatically at 160 lb. pressure, furnishing the steam supply for various steam engines, miscellaneous plant usage, and, when necessary, the 160 lb. throttles of the 3000 kw. units. Exhaust steam from mill engines, at 2 lb. gauge pressure, is used for power generation in the 3000 kw. mixed pressure units, which will carry 2000 kw. each on 2 lb. steam alone. If more than 2000 kw. is required, steam is drawn from the 160 lb. system.

The 7500 kw. turbines are equipped with surface condensers of sufficient capacity to permit operation of the turbines as non-extracting units at full rated load. Condenser water is circulated over a forced draft cooling tower, designed to cool 22,600 gal. of water per min. through a 15 degree temperature range. The 3000 kw. turbines exhaust into barometric condensers which are supplied with cooling water from a spray pond with a capacity of 15,000 gal. per min.

The original installation was composed of the two 3000 kw. units, and generated three phase power at 2300 volts, 60 cycles. All outgoing feeders were for 2300 volt service, as were the two 1000 kw. synchronous motor-generator sets for auxiliary d-c. power. In plan-

ning the more recent 7500 kw. units, which were to supply power for the hot and cold strip mills, it was deemed advisable to generate at a higher voltage. All outgoing feeders to the hot and cold strip mill and to the North plant are for 6900 volt service. To secure maximum economy and flexibility, a bank of three 2500 kva., 6900/2300 volt transformers was installed, so that all turbines may be operated in parallel. All turbine units, as well as several bus-tie breakers, are arranged for automatic synchronization.

The connected load on the power plant totals approximately 50,000 hp.; the installed generating capacity is 21,000 kw. at 80 per cent power factor. There is, however, sufficient synchronous equipment in the plant to maintain unity power factor at all times, so that the generating capacity is actually 25,000 kw. Peak swings up to approximately 22,000 kw. have been experienced.

Steam is supplied to the consuming units at 420 lb. pressure, 650 degrees F. temperature from three 120,000 lb. per hr. steam generators. They are fired with pulverized coal or natural gas, and equipped with economizers and air preheaters. Two of these units have 5700 sq. ft. of heating surface, 4590 sq. ft. of economizer surface and 15,552 sq. ft. of air heater surface, while the third shows 7831 sq. ft., 6000 sq. ft. and 10,800 sq. ft., respectively. Feed water consists of about half condensate and half make-up, the latter being supplied by a continuous hot process lime-soda softening plant, with supplementary phosphate treatment.

Peak loads imposed on the steam plant are 350,000 to 400,000 lb. per hour. There is no spare unit, all three units being required when the mill is in full operation. The steam generating units are operated under automatic control, the controls being grouped on individual control panels, while a central board carries a complete installation of meters and instruments. Boiler feed pumps and coal pulverizers are driven by steam turbines, while forced and induced draft fans are motor-driven.

Incoming coal is dumped from the cars into a track hopper, from where it is moved by belt conveyor and bucket elevator, with a horizontal run to a 500 ton overhead bin. From this bin are fed six unit type impact pulverizing mills. Eight tangential coal burners are provided on each boiler unit.

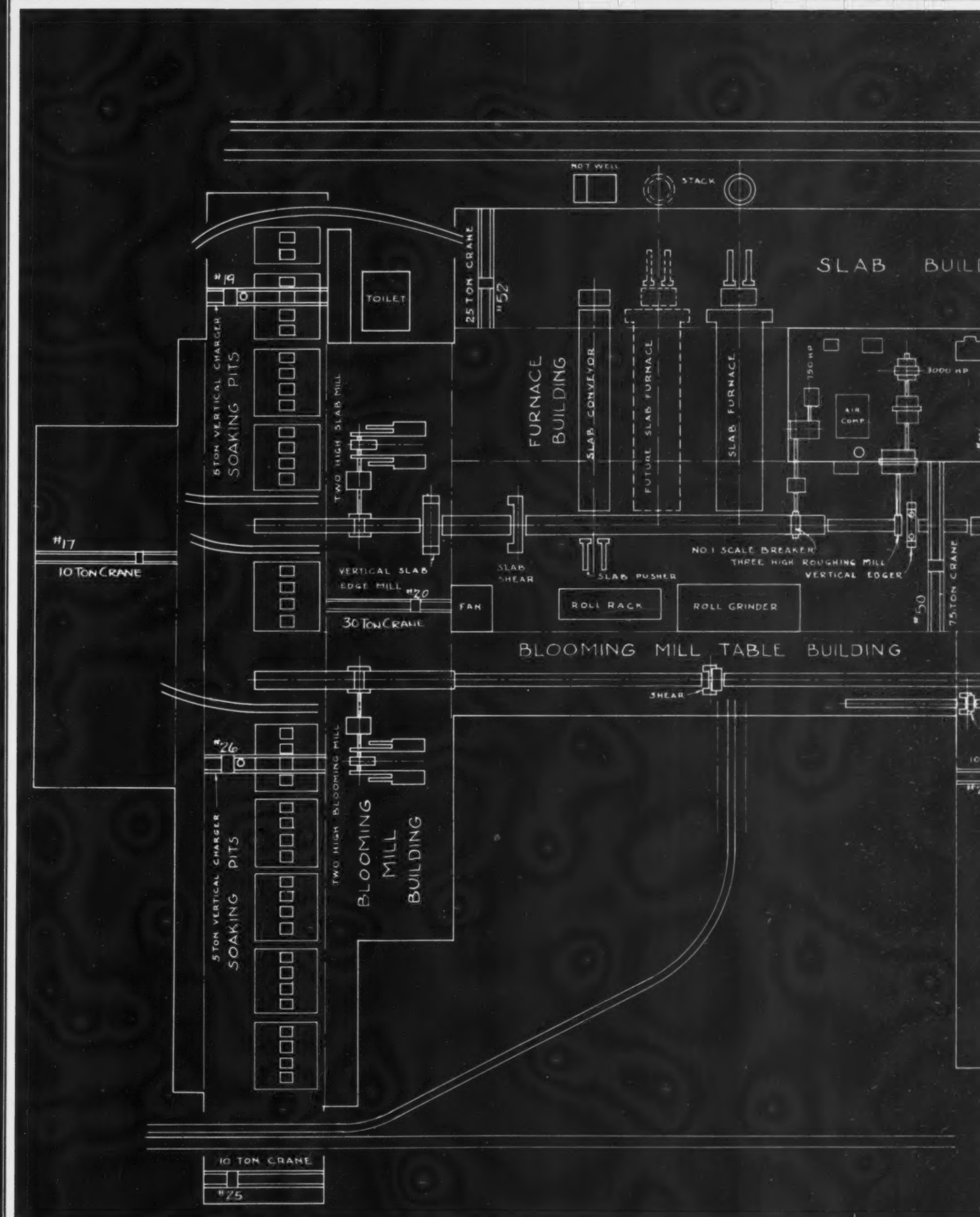
As standby protection, there are also installed auxiliary gasoline engine units for power generation and for water pumping.

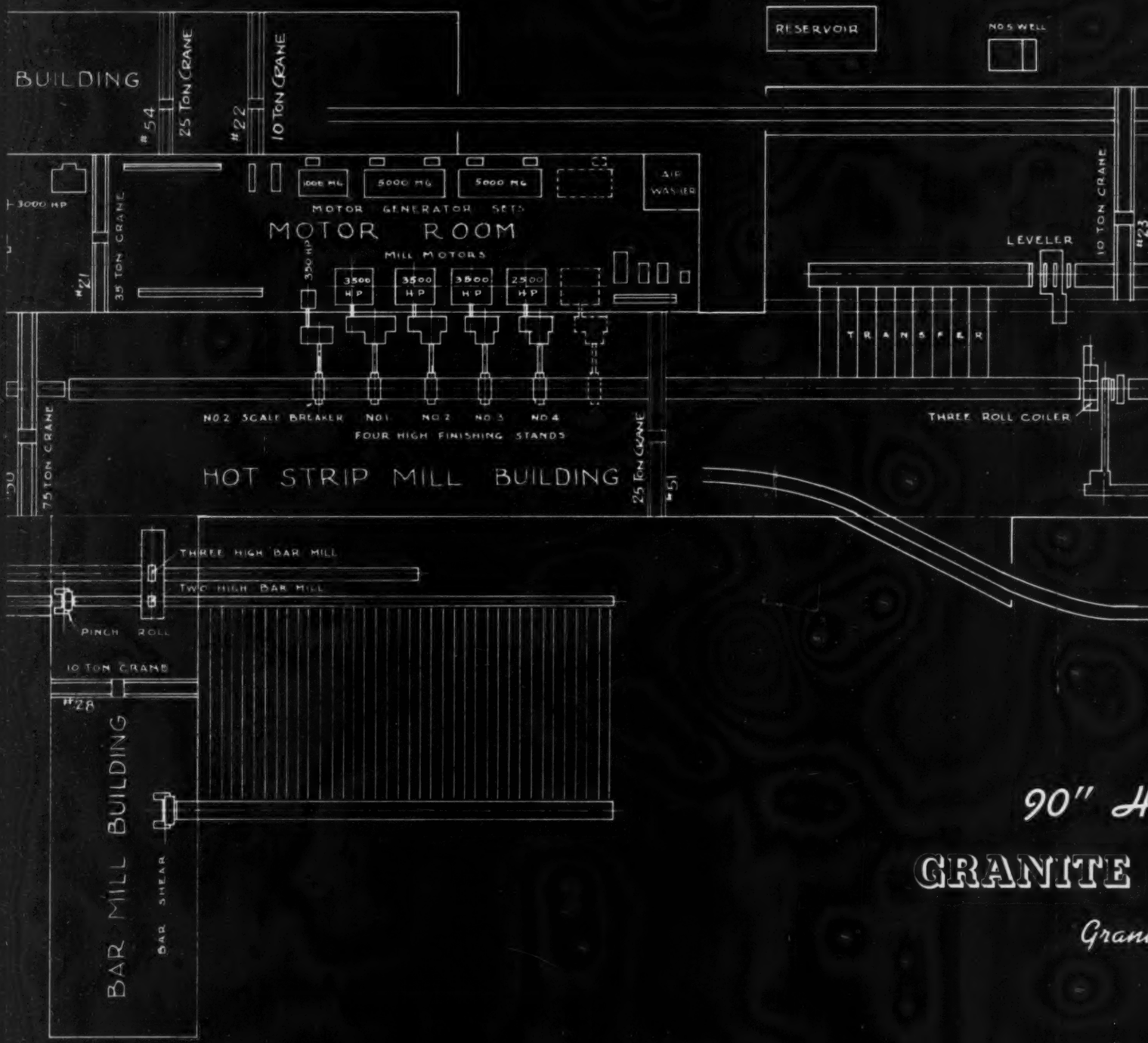
BUILDING AND CRANE DATA

Building	Length, ft.	Width, ft.	Cranes		
			Number	Capacity, tons	Span, ft.
Soaking pit building	440	54	2	15	50
			2	5	50
Slabbing mill building	312	54	1	20	50
Slab storage	366	54	1	10	50
			2	25/10	50
Furnace building	145	51	1	10	51
Hot strip mill building	1115	74	1	75/25	70
			2	25	70
Hot mill motor room	310	54	1	35	50
Plate shipping building	536	79	3	10	75
Coil storage building	154	54	1	10	50
Cold strip coil handling	426	45	2	10	42
Cold mill building	282	79	1	50/10	75
			1	15	75
Temper mill building	244	79	1	50/10	75

MILL DATA

Stand	Characteristics	Diameter		Roll body length (in.)	Motor			
		Work rolls (in.)	Back up rolls (in.)		Hp.	Volts	Rpm.	Type
Hot Mill								
Roughing scalebreaker	1 stand, 2 high	30	..	100	700	6600	505	Ind.
Rougher	1 stand, 3 high	22	34	100	3000	2300	237	Ind.
Finishing scalebreaker	1 stand, 2 high	27	..	90	350	600	450/900	d-c.
No. 1 finisher	1 stand, 4 high	26½	53	90	3500	600	175/350	d-c.
No. 2 finisher	1 stand, 4 high	26½	53	90	3500	600	175/350	d-c.
No. 3 finisher	1 stand, 4 high	26½	53	90	3500	600	175/350	d-c.
No. 4 finisher	1 stand, 4 high	26½	53	90	2500	600	225/450	d-c.
Cold Mills								
Reversing mill	1 stand, 4 high	16¾	52	48	1250	600	350/585	d-c.
	Reels (2)				(2) 500	600	400/900	d-c.
Reversing mill	1 stand, 4 high	16¾	52	48	1750	600	300/640	d-c.
	Reels (2)				(2) 800	600	400/900	d-c.
Temper mill	1 stand, 4 high	18½	52	48	500	600	200/500	d-c.
	Tension rolls				500	600	200/500	d-c.
	Reel				150	250	400/1200	d-c.
Skin pass mill	1 stand, 2 high	30	..	90	500	2300	350	Ind.

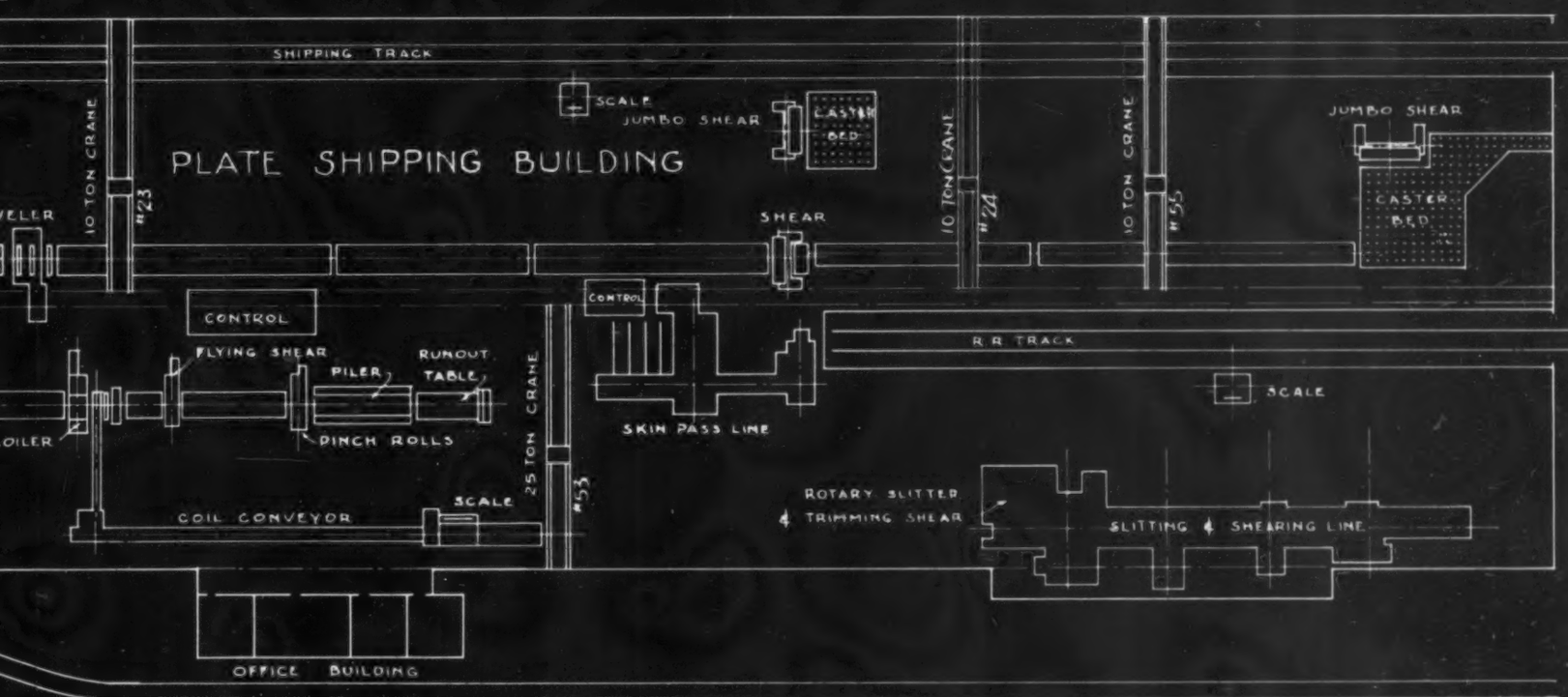

HOT WELL
STACK
SLAB BUILD
25 TON CRANE
#52
#19
TOILET
5 TON VERTICAL CHARGER
SOAKING PITS
TWO HIGH SLAB MILL
FURNACE BUILDING
SLAB CONVEYOR
FUTURE SLAB FURNACE
SLAB FURNACE
750 HP
3000 HP
AIR COMP.
#17
10 TON CRANE
VERTICAL SLAB EDGE MILL
#20
30 TON CRANE
SLAB SHEAR
SLAB PUSHER
NO. 1 SCALE BREAKER
THREE HIGH ROUGHING MILL
VERTICAL EDGER
FAN
ROLL RACK
ROLL GRINDER
#50
75 TON CRANE
BLOOMING MILL TABLE BUILDING
SHEAR
#26
5 TON VERTICAL CHARGER
SOAKING PITS
TWO HIGH BLOOMING MILL
BLOOMING MILL BUILDING
10 TON CRANE
#25



90" H

GRANITE

Gran

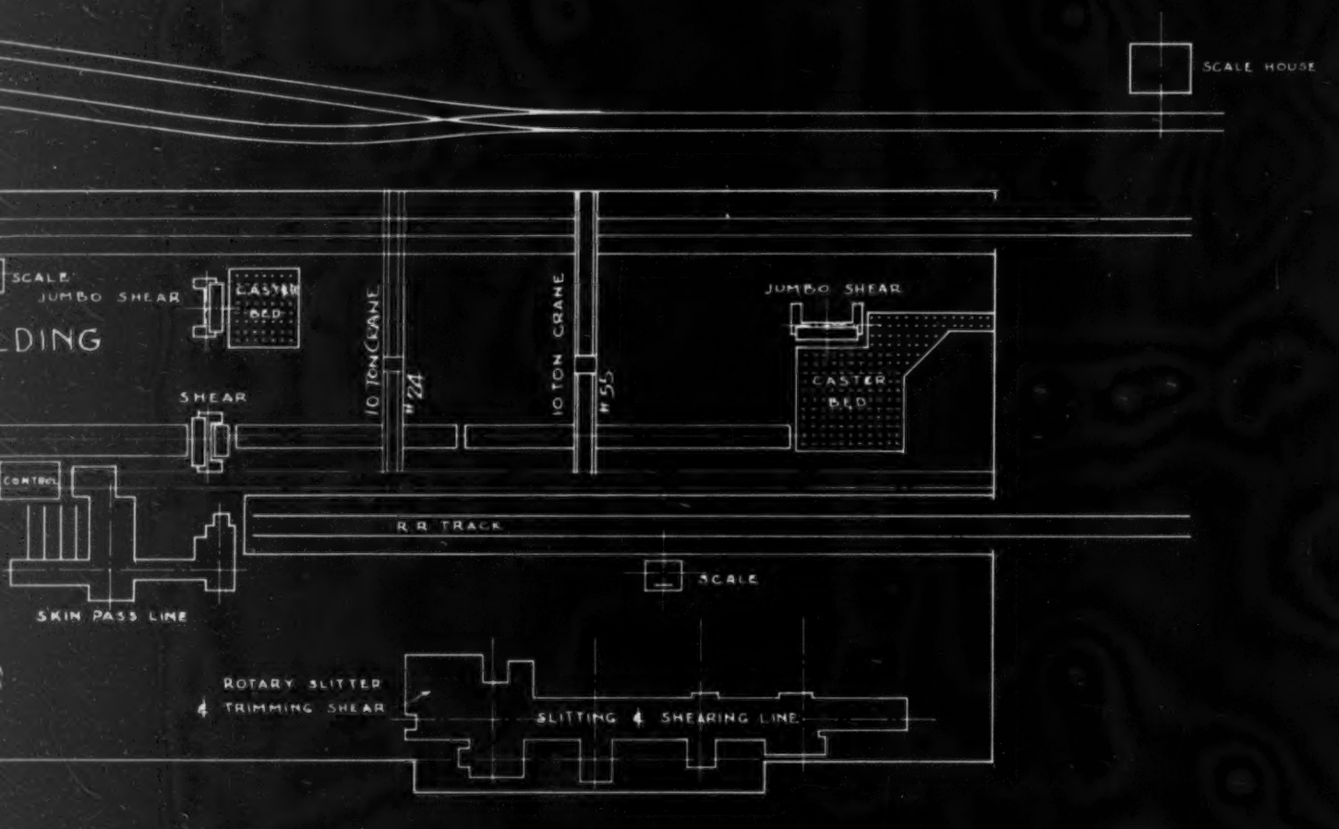


90" Hot Strip Mill

NITE CITY STEEL CO.

Granite City, Illinois

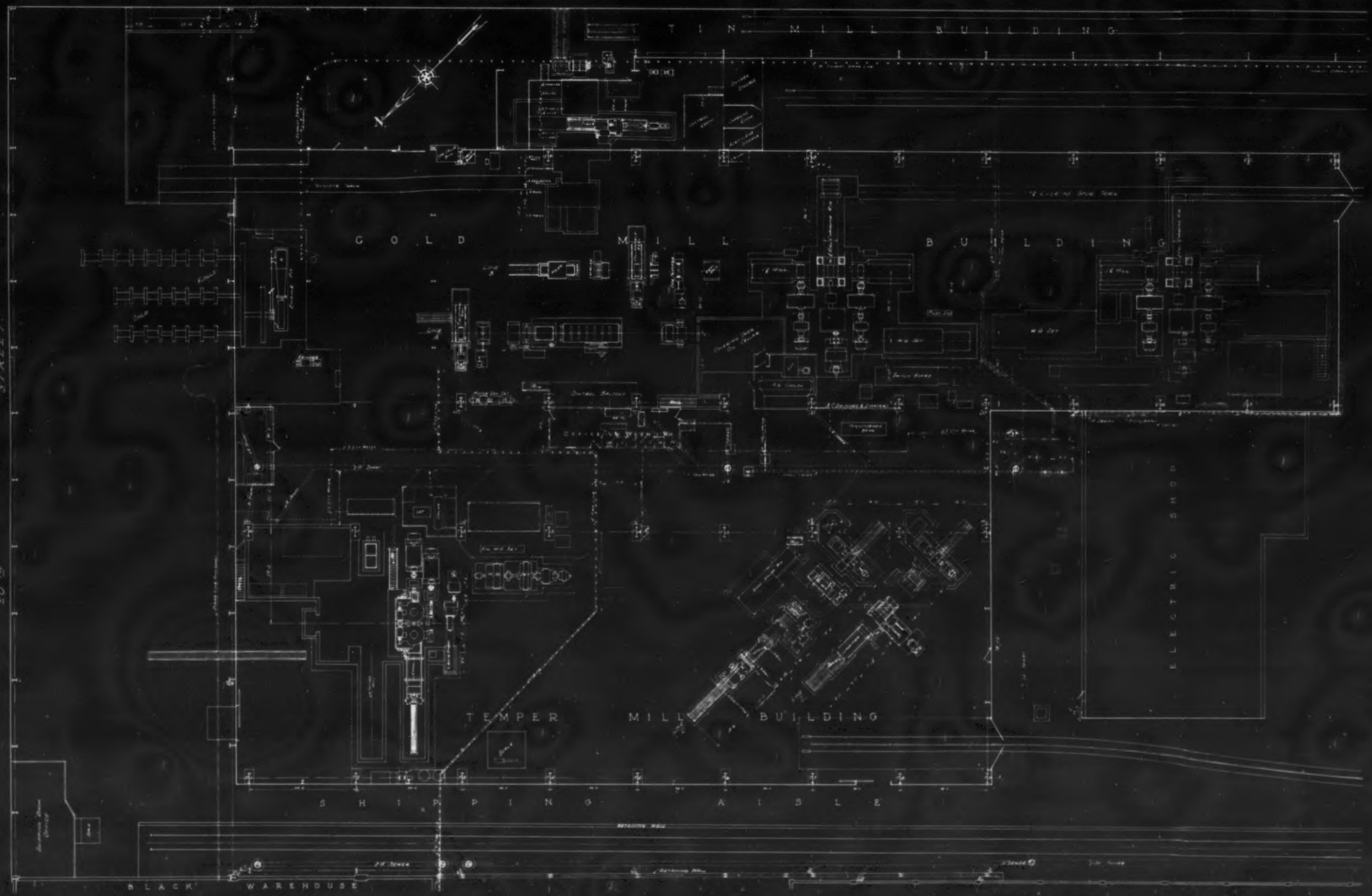
SCALE; 1" 40'-0"



Cold Mill, Temper Mill and vicinity

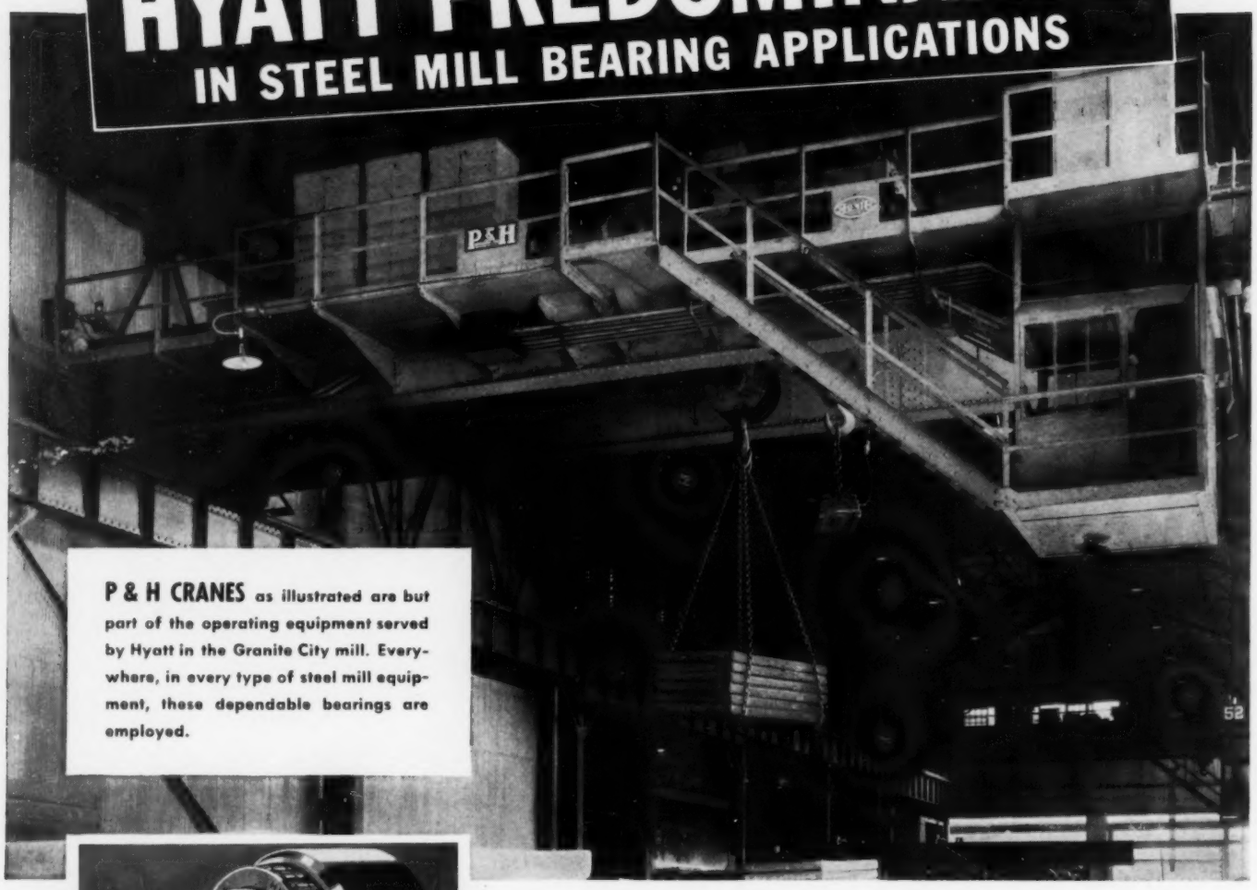
Cold Mill, Temper Mill and vicinity

GRANITE CITY STEEL CO.

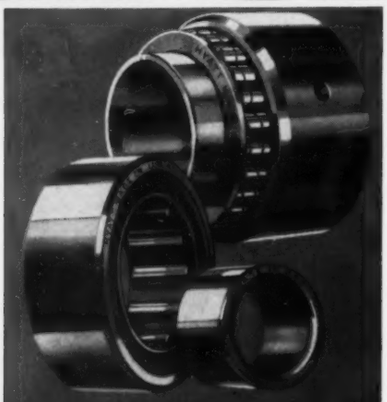


ADVERTISING PAGES REMOVED

ANOTHER EXAMPLE OF HYATT PREDOMINANCE IN STEEL MILL BEARING APPLICATIONS



P & H CRANES as illustrated are but part of the operating equipment served by Hyatt in the Granite City mill. Everywhere, in every type of steel mill equipment, these dependable bearings are employed.



HYATT
ROLLER BEARINGS

As further evidence of the fact that Hyatt Roller Bearings are everywhere in steel mill service we cite outstanding applications at the Granite City Steel Company plant. Ingot and charging cars, tilting tables, lineshafts and table rolls in the hot strip mill, cranes ...all running smoothly and carefree on Hyatt Roller Bearings.

In mill after mill, in every section of the country, on all kinds of equipment, you will find Hyatt Roller Bearings used just as extensively. If you are contemplating the purchase of new equipment or changeovers, let us help you on your bearing applications. Hyatt Bearings Division, General Motors Sales Corporation, Harrison, New Jersey; Detroit, Chicago, Pittsburgh and San Francisco.

18. stand of 8. Merchant Mill—
Ryertex Bearings throughout.

Power Costs *Reduced* 25% .. Bearing Life *Increased* 600% on this typical Ryertex Installation

About 21 months ago a large eastern mill replaced brass and bronze bearings on their 18″, 12″, and 8″ rolling mills with Ryertex composition Bearings. The former metal bearings required special greases and wore out in three months' time. The water-lubricated Ryertex Bearings have not only given trouble-free wear for the last year and three-quarters but have also reduced power costs about 25%.

This report, along with many others, proves conclusively that Ryertex Bearings not only last longer than other types of bearings, but reduces power and lubrication costs as well. Ryertex Bearings are water lubricated eliminating grease and oil expense and increasing plant safety and cleanliness. Ryertex Bearings have a low co-efficient of friction (approximately 1/3 that of Babbitt) which helps to centralize wear along the axis of the bearing thus helping keep rolls in better alignment. The low co-efficient is in a large measure responsible for reduced power consumption and long bearing life. Slow rate of wear reduces the need for frequent roll adjustment permitting rolling to closer tolerances and reducing scrap losses.

In addition to moderate initial cost, Ryertex Bearings necessitate no radical change in housing when they are installed to replace bronze or babbitt liners.

These bearings are being used in all types of rolling mills. We shall be glad to send complete data on any particular installation in which you are interested.

JOSEPH T. RYERSON & SON, INC.
Chicago, Milwaukee, St. Louis, Cincinnati, Detroit, Cleveland, Buffalo, Boston, Philadelphia, Jersey City.

RYERSON

Developments in

ELECTRICAL PRECIPITATION

in STEEL PLANTS

▲ PROGRESS in any art is measured to a large degree by the new developments which are occurring within that art. In the case of gas cleaning, these new developments, to be of technical importance, must be translatable to an industry or group of industries and must be, preferably, such that their use is realized on a commercial scale. The new developments occurring in the application of the electrical precipitation equipment to steel plant problems during the last ten years have taken the form of direct application of the equipment for particular phases of the industry. It is the purpose of this paper to describe rather generally the equipment used for the various steel plant problems and to discuss the results secured with this equipment.

Extensive utilization of electrical precipitation in steel plants has occurred chiefly during the past decade. Prior to 1930 there were a few scattered installations, some of which were described by C. W. Hedberg in a paper published in the IRON AND STEEL ENGINEER of July, 1929. Much experimental work had been carried on both here and abroad but relative to the number of potential applications its utilization in steel plants up to that time had not kept place with its rapidly expanding use in other fields such as non-ferrous metal smelting, sulphuric acid, manufactured gas, pulverized coal fired boiler operations, etc. Since that time the picture has changed considerably so that at present an electrical precipitator is an accepted and widely used piece of equipment in steel plants.

Information on the fundamental principles as well as the utilization of electrical precipitation have been given in numerous articles and papers so that only the salient features pertaining thereto will be considered here.

Electrical precipitation is used for the purpose of removing suspended material, either liquid or solid, from a gas. It is carried out in three distinct steps which may occur simultaneously or separately. The first step consists in electrically charging the suspended particles in the gas stream, which is effected by means of a corona discharge produced adjacent to one of the electrodes. The gas is then made to pass between electrodes where a strong electric field is maintained which causes the charged particles to migrate out of the gas stream and collect on one or both of the opposing electrodes. This is the second, or precipitating, step. Finally the precipitated material is removed from the electrodes to the hopper or other central collecting point.

The utility of electrical precipitation results largely from the fact that it is applicable over such a wide range of conditions. As previously stated, it is equally effective on liquid or solid particles. The same applies to particle size as the equipment is effective on any particle, ranging from the smallest fume or fog particle or so-called "smog" up to cinders such as are present in combustion gases from boilers. Either electrically conducting or non-conducting particles can be charged and precipitated. Under proper control it can be carried out under any temperature conditions for which suitable materials are available for construction of the electrodes. Likewise, it is effective under varying gas pressures ranging from below atmospheric up to 400 lb. gauge which, at present, is the maximum at which precipitation has been attempted.

In its practical applications, electrical precipitation is carried out in equipment which permits of considerable latitude in design. There are two essential elements of such equipments. One comprises a shell fitted with suitable inlet and outlet gas connections and which is equipped with hopper or some other type of precipitate collecting chamber. The other is the electrical equipment which supplies the high voltage unidirectional current used to energize the precipitator proper.

Electrical precipitation installations may be classified into four general groups depending on the purpose for which they are provided. These are:

1. For collection of values from gases before they are wasted to atmosphere.

By C. W. HEDBERG

and L. M. ROBERTS

TECHNICAL AND DEVELOPMENT DEPTS.

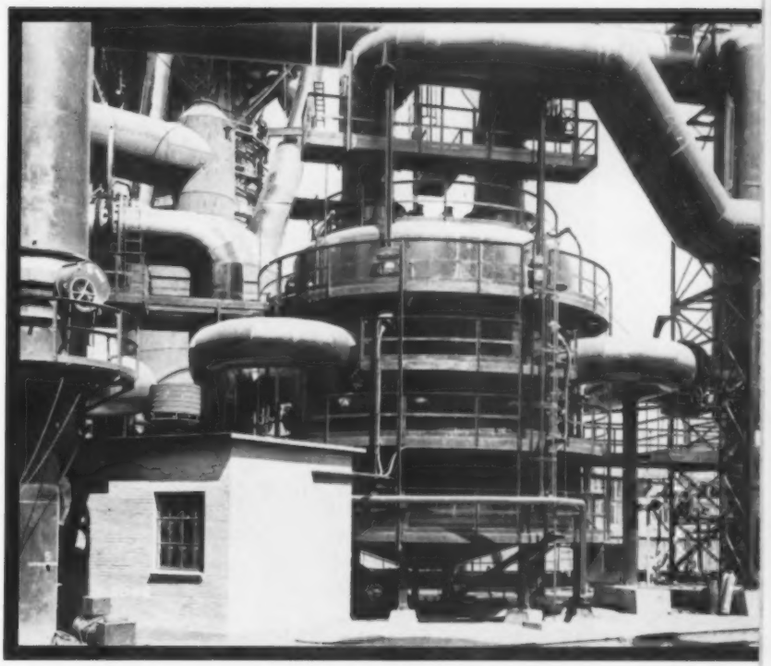
RESEARCH CORPORATION

BOUND BROOK, NEW JERSEY

Presented before A. I. S. E.

PITTSBURGH DISTRICT SECTION

February 13, 1940



The electrical precipitator, applied to secondary cleaning of blast furnace gas, produces a clean, dry gas at low cost.

2. For elimination of a nuisance or hazard that may result from presence of suspended matter in gases which are discharged to atmosphere.
3. For removal of suspended matter from gases prior to the utilization of these gases for industrial purposes in which the presence of suspended matter is objectionable.
4. For a combination of two or more of the individual purposes in the preceding groups.

Most steel plant installations to date come under group 3 and comprise chiefly installations for cleaning blast furnace gas and coke oven gas. In some of these instances, although the gases are cleaned primarily for subsequent use, there have been sufficient auxiliary benefits in the form of reduced smoke nuisance, when the products of combustion of these cleaned gases are discharged to atmosphere, to permit classifying these cases under the fourth group.

As agitation against discharge of gases containing objectionable suspended material becomes more pronounced, it is possible that an increasing number of installations may be of the second group. For example, as steel plants extend the use of pulverized coal for boilers, it ultimately might be necessary to give consideration to collection of fly ash from the stack gases and installations for this purpose would be typically second group.

Since most precipitator applications in steel plants have been in two principal fields, *i.e.*, cleaning blast furnace gas and cleaning coke oven gas, it is only natural that developments, such as have been made, should be chiefly in connection with these applications. Accordingly, they will be discussed under these headings.

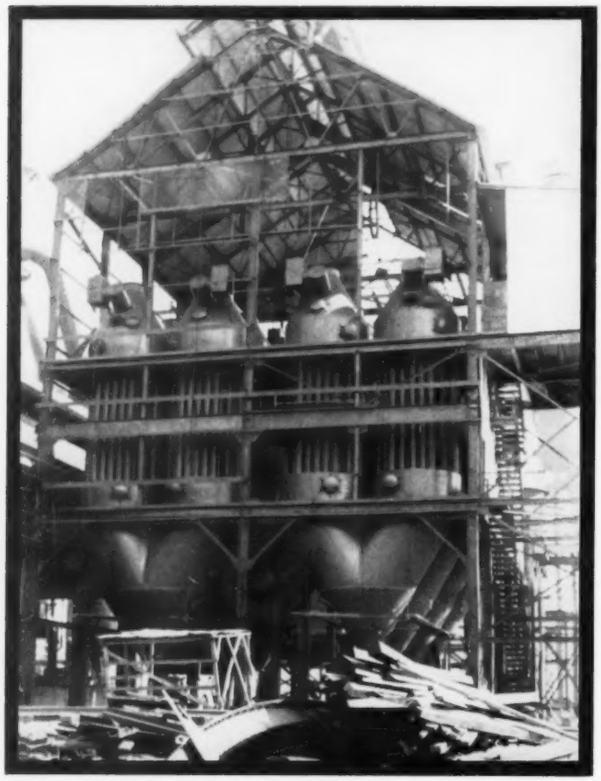
PRECIPITATORS FOR BLAST FURNACE GAS CLEANING

No other metallurgical operation produces so much by-product gaseous fuel as the iron blast furnace. One of the outstanding developments in recent years in steel plant practice is the progress made in increasing and improving the use of this gas as fuel with resultant economies in steel production. The successful utilization of the gas, however, requires the removal of the dust and fume, the extent to which this cleaning is carried being dependent upon the ultimate use of the gas.

In general, electrical precipitation equipment has been applied in the United States to both primary and secondary cleaning. However, during the last ten years, the emphasis has been placed on secondary cleaning and, as a matter of fact, no commercial installations on primary gas cleaning have been installed during this period. Since this paper is concerned with the newer developments of the art we will not discuss primary cleaning other than to refer to the previously mentioned paper by C. W. Hedberg which reviewed the status of precipitators for primary cleaning here and abroad up to and including those in commercial usage in 1929.

As stated heretofore, the emphasis in blast furnace gas cleaning has been greatest in the field of secondary cleaning. The growth in interest in this field is attested by the fact that in 1929 there was one unit in operation, on a more or less experimental basis, treating 15,000 cu. ft. per min., while in January, 1940, there were in operation and under contract 33 precipitators with a treatment capacity of 1,454,400 cu. ft. per min. While the majority of these installations were installed in the United States it is of interest to note that there are five located in India and six in Australia.

The technical problems encountered in adapting electrical precipitation to secondary blast furnace gas cleaning were relatively few. Contrary to expectations, the



This construction view shows exposed pipe precipitator installation for cleaning gas from a ferro-manganese furnace.

most difficult of these was in connection with removal of the precipitate from the electrodes. It had been anticipated that the water entrainment normally in the primary washed gas would be ample to flush any solid precipitate from the electrodes as it deposited, particularly if it was augmented intermittently by flushing. In practice, however, it was found that a relatively free flowing precipitate or slurry would form on the leading portions of the collecting electrodes while on the trailing portions there would be a relatively dry deposit with a pronounced tendency to cement itself to the electrode surfaces. Evidently in primary washed gas there are a considerably number of particles which have not become wetted. Intermittent flushing would not remove these deposits and as they continued to build up, precipitator performance, both as regards capacity and cleaning efficiency, was not satisfactory. It soon became apparent that successful application of electrical precipitation required the development of a continuously wetted electrode from which the precipitate would run off as rapidly as it was deposited.

The solution to this problem which was finally adopted took the form of vertical tubular collecting electrodes, the upper ends of which are fitted into a header plate. The top-side of this header plate is divided up into ponds by means of vertical metal strips welded to the header and which enclose uniform groups of pipes. An adjustable weir ring is then fitted to the top of each pipe and the top edges of all weirs in an individual pond are adjusted to the same level. Controlled amounts of water are then supplied to each pond and this overflows uniformly and runs down the inside surface of each pipe collecting electrode. A satisfactory water film can be maintained in this way with as little as 1½ pints of water per minute for an 8 in. inside diameter pipe, although in practice it is customary to increase the flow up to approximately 5 gal. per min. for 5 minute periods two or three times a day.

A further refinement consists in adding wetting agents to the water supplied to the ponds, as for example 25/100 of 1 per cent silicate of soda. This is not an essential but it does provide a reserve method in case stubborn deposits are encountered.

A second problem was in connection with equipment for energizing the precipitators. Normal rectified high voltage alternating current with power impulse on each half cycle was satisfactory from the precipitator performance standpoint. However, power consumption was high and a single electrical set would serve a comparatively small number of electrodes thereby increasing the initial cost of the electrical portion of an installation.

This led to the development of so-called half-wave electrical sets. With this equipment two instead of one bank of electrodes are connected to a single rectifier and a power impulse is supplied to each bank on alternate half cycles rather than on each half cycle. Capacity and cleaning efficiency of the precipitator were not affected by this change but there resulted a decrease of approximately 40 per cent in power consumption and, except for the smaller size precipitator units a reduction of approximately 50 per cent in cost of electrical equipment.

The only other major problem, and this is specific to each case, has been in connection with selection of proper size and number of precipitator units and their

View of coke oven gas de-tarring installation, showing three precipitators, with substation building at right.

adaptation to existing equipment. These have resulted in some interesting solutions, among which might be mentioned the erection of precipitators on top of primary scrubbers.

The cleaned gas from the precipitators is used primarily for the following purposes:

(a) Stoves
(b) For metallurgical use either alone or mixed with coke oven gas
(c) For underfiring coke ovens
(d) For gas engines

Gas cleaned to any desired limit on permissible dust content for the above purposes can be readily obtained by regulating the rate of gas passing through a precipitator. Tests made by the accepted Brady method have indicated that the design expectations in each case have been met. Tests made on units that had been in operation over extended periods indicate that the cleanliness is maintained in continued service and also that the precipitator not only removes the suspended solids but also the entrained water and delivers a so-called dry gas.

Of paramount importance to the steel plant operator is the low operating cost of a precipitator. The items comprising the cost elements are electric power, steam, water and operating labor. The electrical power consumption averages between .4 and 1.0 kilowatt-hours per 100,000 cu. ft. of gas cleaned, depending to a large degree on the volume handled in individual units and the cleanliness desired.

The total water consumption, including overflow for the collecting electrodes and the amount required for flushing, averages 150 to 500 gal. per 100,000 cu. ft. of gas. Clear water reasonably free of constituents corrosive to materials of construction is desired. However, with proper control, salt water as well as waters containing fairly high contents of suspended and dissolved solids have been successfully used. The intermittent flushing referred to above is done while the precipitators are energized so that there is no interruption in operation for precipitator cleaning. From an effluent standpoint, the amount of water required is small as compared, for example, with the volumes used in scrubbing.

The pressure drop between inlet and outlet of the precipitator is less than ½ in. of water, which represents a negligible cost for power.

The amount of labor required to operate any type of secondary cleaner depends largely upon local conditions. Since there are few moving parts to the precipitator equipment, labor required for operation and maintenance will necessarily be very small.

Costs computed by an independent engineer on a precipitator for treating primary cleaned gas containing .25 grains per cu. ft. and producing an outlet gas of .009 grains, indicate that costs of power, steam and water would be $.005 per 100,000 cu. ft. On another installation the costs for these items was about one cent.

We believe that the electrical precipitator has earned through ten years of plant use, in which its practicability has been demonstrated, a permanent and eminent position in the field of secondary gas cleaning equipment, and that it provides a practical and permanent solution to the problem of obtaining clean blast furnace gas.

THE CLEANING OF FERRO-MANGANESE GAS

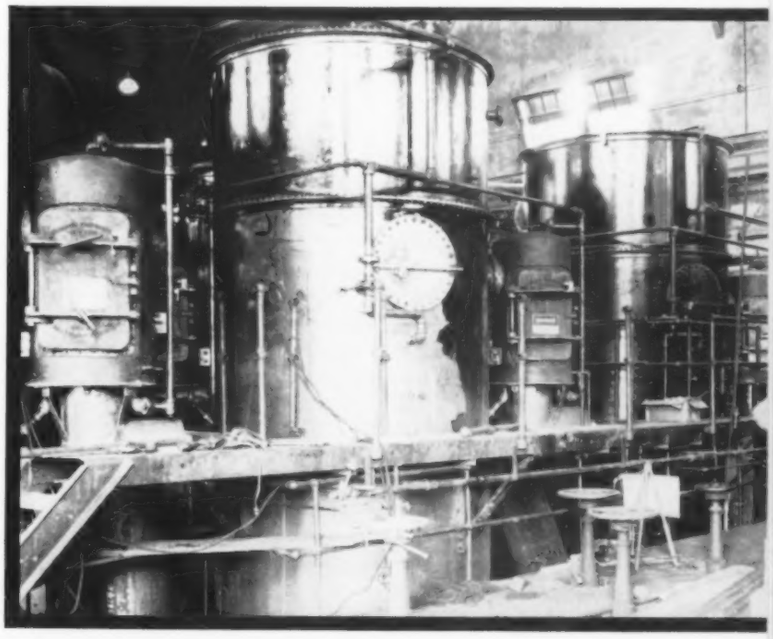
While most installations of electrical precipitators in connection with blast furnace gas cleaning are and probably will continue to be for secondary cleaning in conjunction with primary scrubbers, its usefulness is by no means limited to such a combination. Such factors as limited water supply, difficulties in connection with disposal of scrubber effluents, values in the recovered dust, loss of useful heat in the furnace gases in scrubbing, and condensible constituents in the raw gas that would clog wet scrubbers if these were used, are some of the reasons why electrical precipitators have been installed during the past decade for dry cleaning of blast furnace gas.

Of particular interest in this connection are installations of electrical precipitators on two ferro-manganese furnaces. The solids content of these gases is materially higher than in iron blast furnace gas and it is largely composed of fumy material of extremely fine particle size. Furthermore, downcomer temperatures are very much higher and all of these factors contribute to make it a rather difficult cleaning problem.

Because of lack of experience in this application these installations were preceded by tests on a pilot plant scale. These indicated that by partial cooling and by the addition of a limited amount of water vapor such as would result from water added to the furnace top for cooling purposes, it was possible to remove the solids to a residual content of .06 grains or less per cu. ft. and recover them in a dry state.

Based on the findings in this pilot plant test an installation was built having a capacity of 60,000 to 70,000 cu. ft. per min. This was greatly in excess of what could be handled in a single unit, so that the plant comprised 8 parallel units, which also provided some reserve capacity for outages on individual units for servicing.

Precipitators for de-tarring coke oven gas are of the pipe type, and may be installed either indoors or outdoors.



These units are of the tubular collecting electrode type. The pipes are not enclosed in a shell, and the heat loss from these to the surrounding atmosphere provides most of the cooling of the gases necessary for best precipitator performance.

The units are divided into a down-flow and an up-flow section, each comprising 42 pipes approximately 10 in. in diameter and 15 ft. long. The gases enter one half of the divided top header, pass downward through the first section of pipes to the bottom header, which is hoppered to receive the precipitated dust, and thence through the up-flow section of pipes to the other half of the top header from which they enter the clean gas main. Automatically controlled motor-driven rappers are provided for removing the precipitated dust from both the collecting and discharge electrodes to the hoppers.

Provision was made for automatic control of temperature and moisture content of the gases entering the precipitator within desirable limits as established from pilot plant operation. In practice it was found that the amount of moisture present in the gas as a result of water addition to the furnace top was in excess of requirements so that for all practical purposes the equipment handled the gases direct from the furnace without the need of close control.

One of the principal problems encountered in operation of this installation was hopper dumping and disposal of the precipitated dust amounting to some 24 tons of very low density material per day. Dust content of the cleaned gas was of the order of .06 grains of dry material per cu. ft. and less, which made it a very satisfactory gas for stove and boiler use.

HIGH SILICON IRON FURNACES

The use of electrical precipitators as dry cleaners has also found application in connection with high silicon iron furnaces where non-coking coal is supplied in the burden both as fuel and for cooling the furnace top. These gases like those from a ferro-manganese operation leave the furnace at high temperatures and contain a high solids content which is largely fume and therefore composed of extremely small particles. In addition they contain tar vapors, distilled from the added coal, in variable amounts depending on the amount of coal added.

High stove heats are an essential in these operations and these are not easy to obtain when using raw gas for stove heating. Also those grades of iron requiring the highest stove heat produce the highest solids contents in the gases and consequently if raw gas is used stove deterioration is greatest at just those times when best stove operation is most desired.

Attempts to clean these gases by scrubbing were not successful. The tar vapors condensed and in combination with the solids, formed masses of heavy pitch which clogged the scrubbers and made them inoperative. Furthermore, the disposal of effluents because of their phenolic contents would have presented very serious difficulties. A secondary objection to wet scrubbing was the loss of heat value which would result partially from temperature reduction but chiefly from removal and wasting of the natural tar content.

The problem in this case, therefore, was to remove the dust from the gases at a temperature above the dewpoint of the tar vapor. A precipitator was designed to operate at temperatures ranging from 350 to 600 degrees F., at which temperature the dust was removed in a tar free state. These precipitators were of the plate type and consisted of composition plate collecting electrodes and wire discharge electrodes. The electrodes were arranged in a rectangular shell which was surrounded by a circular outside shell. The gases entered the circular shell, passed downward in area on the outside of the rectangular shell and then upward through the precipitating area. Three precipitators were installed, each consisting of 8 ducts. It was necessary to insulate the precipitators and flues to conserve heat and prevent tar deposition. The precipitators were supplied with scrapers for collecting electrode cleaning, and rappers for removal of deposits from the high tension discharge electrodes.

The gas cleaning system at these plants consists of a primary dust catcher and the precipitators only. The builder's tests made at the time of the installation showed efficiencies of approximately 97½ per cent. The precipitated dust was substantially tar free. The intangible items, such as higher stove temperatures and less stove maintenance, have more than proved the worth of precipitators on this problem.

DETARRING COKE OVEN GAS

In practically every method of gas generation it is desirable to obtain the highest possible removal of the suspended tar and oil prior to final distribution or subsequent chemical treatment for the recovery of volatile by-products or absorption of gaseous impurities. In coke oven plants the presence of tar and oil will result in the contamination of the sulphate. Also, the tar and oil have a definite market value which justifies its recovery for sale or use.

The removal of tars and oil from manufactured gas by electrical precipitators had its origin in the carburetted water gas industry. Here tars are removed prior to the sulphur removal stage. The first commercial installation was made in 1924 and it was not until 1927 that precipitators were applied to coke oven gas. Since this initial installation 60 precipitators have been installed on coke oven gas with a normal capacity of 700 million cu. ft. per day.

In general, the precipitators used for this service are of the pipe type consisting of a steel shell in which are grouped a number of pipes 6 or 8 in. in diameter by 9 ft. long. The pipes pass through a header plate at their upper ends, the gas connections to the shell being arranged so that gas enters the lower portion of the shell below the header plate and thence passes upward through the pipes into the upper compartment to the gas outlet. Rods are suspended in the center of each pipe from a framework carried on insulators located in compartments on the sides. Weights are attached to the lower ends of the rods to keep them taut.

Under electrical action the suspended tar and oil is driven out of the gas to the interior walls of the pipes from which the liquid flows by gravity into the lower header of the precipitator. From here the tar flows

through a seal to the tar sump. The size of the precipitator and number of pipes required depends upon the volume of gas to be treated. For a large gas volume, however, it is usually desirable to install multiple precipitator units instead of one large unit for the sake of flexibility of operation.

In some instances the precipitator is located ahead of the exhauster, while in others it follows the exhauster, so that the pressure will range from 1 in. Hg suction to 3 in. Hg pressure. In all cases the precipitators follow the coolers so that the temperature ranges from 70 to 125 degrees F.

The precipitators are usually rated for the removal of 90 to 95 per cent of the tar and oil present in the inlet gas though ratings of 98 per cent are not unusual. It is possible to remove practically all of the suspended matter present in the gases though ratings above 99 per cent are not very practical in that it is extremely difficult to measure with present field methods these extremely high efficiencies.

In the installation and operation of the sixty precipitators mentioned above, a very complete history of performance has been secured. Efficiencies guaranteed have been met in every instance and furthermore, these efficiencies continue indefinitely. Recently a check on an installation was made, about seven years after it was initially installed, and the results indicated that efficiencies at the present time were equal to those obtained during the builder's test period.

The equipment has been thoroughly standardized and is simple to operate. Operating costs are low. Electrical power consumption ranges from 4 to 10 kilowatt-hours per million cu. ft. of gas cleaned. Maintenance is nominal as the precipitator is self-cleaning so that shutdowns for cleaning the precipitator are a very infrequent occurrence. Such occasional attention as is required for cleaning insulators and for care of electrical equipment can be readily applied as part of the routine duties of the plant personnel.

The pressure drop across the precipitator is less than a quarter inch of water as compared with a drop of 8 in. and higher with other types of tar extractors.

Finally, the utilization of electrical precipitation in coke oven practice has proved through the years to be a workable, economical and efficient method of removing tar and oil from the oven gases.

CLEANING COKE OVEN GAS UNDER HIGH PRESSURE

There have also been some interesting special applications of precipitators to manufactured gas among which might be mentioned an installation for practically complete elimination of solid and liquid particles after the gases had been compressed to 125 lb. gauge and cooled to atmospheric temperature.

In general the design of this particular precipitator was similar to the standard unit used for tar removal. Some modifications were necessary in electrical insulation to provide lead-in bushings for the high tension line which would not leak gas at the operating pressures. Also, because of the gas pressure it was necessary to operate at higher voltages than those used on atmospheric pressure installations.

Tests on this installation indicated an outlet gas containing approximately .0002 grains per cu. ft. at 60 degrees F. and 30 in. Hg, which is cleaner than the normal air which we breathe.

In the foregoing, we have attempted to picture electrical precipitator developments during the past decade particularly as they pertain to steel plants. It is an obvious conclusion that they are no longer in what may be termed the novelty stage but, on the other hand, that they are performing a useful function in various applications at numerous points. While most of these have been and probably will continue to be in connection with blast furnace gas cleaning and detarring of coke oven gas it is quite probable that electrical precipitation will prove a useful tool in general or special problems involving solids or liquids removal from gases which steel plant engineers will be required to solve.

While the object of this paper was to outline developments which have occurred during the last ten years, it should be said in closing that studies are being continued at the present time, and it is believed the developments resulting from these studies will result in improved performance and lower initial costs.

DISCUSSION

PRESENTED BY

R. A. NIELSEN, *Research Engineer*, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

L. E. RIDDLE, *Superintendent*, Blast Furnace Department, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

A. F. NESBIT, *Consulting Engineer*, Pittsburgh, Pennsylvania.

B. M. STUBBLEFIELD, *Superintendent*, Blast Furnaces and Coke Plant, Youngstown Sheet and Tube Company, Youngstown, Ohio.

L. M. ROBERTS, Technical and Development Departments, Research Corporation, Bound Brook, New Jersey.

L. C. EDGAR, *Chief Engineer*, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

R. A. FIELD, *Superintendent of Blast Furnaces*, Jones and Laughlin Steel Corporation, Aliquippa, Pennsylvania.

A. J. MacDONALD, Blast Furnace Department, Republic Steel Corporation, Youngstown, Ohio.

J. D. JONES, *Chief Engineer*, Youngstown Sheet and Tube Company, Youngstown, Ohio.

R. H. SCHALLER, *Superintendent*, Coke Department, Jones and Laughlin Steel Corporation, Aliquippa, Pennsylvania.

JAMES FARRINGTON, *Electrical Superintendent*, Wheeling Steel Corporation, Steubenville, Ohio.

H. RICHARDSON, *Engineer*, Research Corporation, Bound Brook, New Jersey.

R. A. NIELSEN: Since the paper just presented was concerned with electrical precipitators for steel mill applications, I would like to mention a couple other

applications for steel mills. There is another design of precipitator which differs considerably from the one just described in that the corona electrode is a wire of about .005 in. diameter, the air flows perpendicular to this wire and then through a series of closely spaced plates, and 13,000 volts is the maximum used. Inherently this equipment is for cleaning air containing low concentrations of dirt, but it has the advantage that the air, when cleaned, is fit to be breathed. Thus one application in steel mills has been for cleaning the air in the laboratories; another is for cleaning the air used for cooling motor-generator sets as well as the motors which are used to drive main rolls such as those used in cold reduction, etc.

L. E. RIDDLE: The only experience I have had with electrical precipitation was when we ran the test plant mentioned on ferro-manganese gas. However, after visiting a number of the modern installations, I feel that the blast furnace men generally are very well satisfied with electrical precipitation, especially for secondary and final cleaning. In the first place, it is cheap, about ½ cent per 100,000 cubic feet per minute. For secondary cleaning it does excellent work, because it is kept continuously in service, it not only holds the dust at a uniform cleanliness but also delivers a dry gas, which is a very essential thing.

It may be of interest to you to know that the man who first brought electrical precipitation to blast furnace men was Professor Nesbit, then of the University of Pittsburgh. In 1912, if I remember correctly, Doctor Cottrell started removing dust from various gases in California. At that time Professor Nesbit came to the Lucy Furnaces with ideas and plans for electrical precipitation of flue dust in the top of the blast furnace. His sketches showed electrodes hanging down below the bell and hopper and in front of the down comer openings. I heard him discuss it. He carried on some experiments in the electrical precipitation of dust from blast furnace gas at the Mingo Junction plant of the Carnegie Steel Company shortly after that.

A. F. NESBIT: About the middle of July, 1912, I joined R. B. Mellon's research staff, on the Smoke Fellowship, at the University of Pittsburgh.

If it were not possible to prevent the production of fumes and dusts in chemical, metallurgical and other processes, it was highly desirable to prevent their escape into the atmosphere. Mr. Mellon's plan was to attack the dust problem at its source, in general, in preference to giving relief only in localities where it had reached the proportion of a nuisance. At the "old smoke house" as it was called at the University of Pittsburgh, we had an assembly of elaborate equipment for the study of electrical precipitation as applied to soft coal smoke and various industrial dusts.

The wire-in-pipe type of electrical precipitator, which was the first set-up at the University, was fully described in a paper presented at the New York meeting of the American Institute of Electrical Engineers, February 19, 1915. In this reference it was shown that the dust settling chamber for the precipitated dust also served as the distributing chamber for the dirty gas, entering from the soft coal furnace or entering from an auxiliary air duct carrying hot or cold air laden with dusts and fumes of different kinds and of different degrees of fineness. The manner of assembling the wire anchoring frames on the symmetrical structure supported by the upper and lower porcelain insulators, may be seen by referring to the paper mentioned.

Even to this day, I have not fully accounted for the reason why the porcelain insulator in the dust settling chamber of this wire-in-pipe precipitator should have given so little trouble while the insulator in the open air gave frequent trouble from flash-overs on its surface.

During a conference with Mr. Riddle and his associates, in 1912, I suggested that while there were practical difficulties to be solved, I believed that it would be possible to install an electrical precipitator of sufficient ruggedness, in the top of a blast furnace, to prevent the dust from entering the downcomer. Such a precipitator, unless properly designed and placed in the top of the furnace, relative to the downcomer and the bells, would suffer awful punishment during a "slip" on the furnace.

I still believe it is possible to install a workable precipitator inside the blast furnace, and keep within the furnace practically all of the dust from the limestone, coke, and ore that has once been hoisted by the skip to the top of the furnace.

Such a solution, as I see the problem, can only be made possible by one or more steel companies pooling their common interests and financing the research work needed. No private concern has the facilities, however attractive this problem is, nor the funds needed, to undertake the research work involved.

It has been mentioned that ¼ in. twisted square rods were used as discharge electrodes placed axially within the 8 in. diameter cylindrical pipes, giving approximately a 4 in. discharge gap. I understand that the voltage used on these precipitators was such as would insure continuous performance, and with a minimum occurrence of spark-overs in the individual precipitator units. It is well understood also, that a disruptive discharge or its degeneration into an arc, in any single pipe unit, completely puts the precipitator out of service during such an interval. At gas velocities, say 10 feet per second in 15 foot 8 in. pipes of 0.349 square feet section, the gas volume handled, per minute, would be close to 200 cubic feet per pipe, and to handle 60,000 cubic feet per minute would require an assembly of 300 pipes. I do not believe that data covering this phase of the problem was given in connection with Mr. Robert's paper.

The rigidity of the discharge electrode system, with the upper and lower tying frames to insure alignment of the individual discharge electrodes, is a commendable feature. Such an alignment of the twisted square bars axially within their respective pipes, serves to reduce to a minimum any tendency to vibration and at the same time insures that the electric fields within the pipes shall be of uniformity of intensity and distribution from the twisted edges.

The escape of certain particles into the air from furnaces gases may be due to the fact that such particles may be slower in acquiring a static charge than other particles that are precipitated during their passage through the treater.

I have personally found that an 18 in. length of ¼ in. pitch screw thread is fully as effective as a twisted square bar many times longer, and at the same time

such a rigid discharge electrode may be very effectively supported from a chamber through which the cleaned gas may pass.

The low voltage at which a discharge will take place from such a discharge edge, as the screw thread, and the almost solid electric field through which the dirty gas has to pass, accounts for the high gas velocities attainable and the efficiency of cleaning.

Perhaps these suggestions may be helpful in cases where certain particles in furnace gases fail to be precipitated.

The chief objections to the use of rectifying tubes for obtaining unidirectional current on the precipitator, is their first cost, their frequent renewals due to their short life under continuous service, and the fact that they are not well adapted where there is a likelihood that they will be subjected to vibration or tremor. Furthermore, even if they are capable of furnishing full wave rectification, they have as yet failed to supplant the mechanical rectifier.

B. M. STUBBLEFIELD: My experience with precipitators does not go back as far as that of Mr. Nesbit's. However, I am gratified to see some of the improvements that have been made in precipitator design during the past few years. It is a source of satisfaction to me personally because our organization in Youngstown campaigned for such changes back in 1932, when the Youngstown job was designed. I have in mind the removable weir ring and rubber gasket seal on the header plate.

Precipitators for gas cleaning are very low cost, highly efficient machines to operate. However, those of us who have to justify capital expenditures for their installation are very much interested in lowering the first cost of the precipitator.

One way to lower first cost is to increase the capacity per unit installed. I would therefore like to ask Mr. Roberts if he would care to comment on the efficiency of precipitator units equipped with 12 in. tubes as compared to the standard design with 8 in. tubes.

Our experience is that a precipitator equipped with 8 in. tubes will remove about 95 per cent of the flue dust contained in blast furnace gas. Examination of the material passed by the precipitator shows it to be of a different make-up than the entering material. In other words the entering blast furnace gas carries a material which is roughly 35 to 40 per cent iron, 10 to 12 per cent silica, some lime, magnesia and soluble alkalies. When we analyze the material which passes the electrical zone of the precipitator, but settles out on the top structure of the precipitator and in the pipe lines, we find it lower in iron content, higher in lime, magnesia, silica, and sulphur content than the entering gas. Furthermore, an analysis of the material carried by the cleaned gas shows it to be about 20 per cent water soluble. About 40 per cent of the water soluble material is sodium and potassium. The insoluble material in the dust collected from the clean gas is very high in calcium, magnesia and silica. All of the above mentioned compounds are very detrimental to brick life.

I am therefore wondering if it is proven the 12 in. tube is less efficient than the 8 in. tube, whether the material passed by the 12 in. tube will contain more of the alkalies and about the same amount of iron as that passed by the 8 in. tube, or will the analysis show about the same proportions as mentioned.

In connection with the corrosion of the steel parts of the precipitator due to water conditions Mr. Roberts mentioned the use of treated water and cadmium plating. The Pittsburgh and Youngstown districts are notorious for the miserable water available for industrial use, so I think it would be of interest to the group to know what the experience has been in coating the entire tube with cadmium. We at Youngstown have had a bad experience in this connection, as our precipitator needs heavy replacements of weir rings and the pipes themselves are badly pitted, although we have purchased the best water available for use on our unit.

What has been done to prolong the life of the electrodes? These rods, as most of you know, are a twisted $\frac{3}{8}$ in. reinforcing bar. The life of these rods is limited due to extreme corrosion at the point of suspension. I personally have always felt the deterioration at this point was due to both corrosion and burning by an electric arc, due to the fact that there is no solid electrical connection between the bus bars and the electrodes.

L. M. ROBERTS: On various problems other than blast furnace gases, precipitators have been used with pipes ranging from 4 to 14 in. in diameter. These have been successful installations and the use commercially of larger pipes is not an innovation.

There are some very interesting factors injected into the selection of the precipitator for blast furnace service.

Heretofore, the demand for precipitators has been for cleaning the gases to a relatively high efficiency; efficiencies above 90 per cent being the rule. No doubt the cleaned gas, in some instances, has been cleaner than actually needed. Of late, there has been a demand for gas cleaning equipment which will not produce as clean a gas but which will deliver a dry gas. Studies were made to adapt the 8 in. pipe for this service, but they indicated that there is a maximum volume beyond which it is not possible to handle in an 8 in. pipe; *i.e.* high back pressure and drifting of water film. These studies were followed by others made on the use of 12 in. pipes.

The studies which were based on results with the use of the 12 in. pipes on other applications indicate:

1. It would be possible to handle higher gas volumes with a 12 in. pipe than with an 8 in. pipe, without encountering the difficulties mentioned above.

2. While it is possible to secure with a 12 in. pipe performances equivalent to that secured with an 8 in. pipe, the question of first cost of the installation enters the picture. Our present studies indicate that for 90 per cent or higher efficiencies the 8 in. pipe is cheaper; for 85 per cent the difference in initial cost is a standoff; and for 80 per cent or lower the 12 in. pipe represents a less expensive installation.

We have no record of the efficiency of removal by a precipitator of sodium and potassium salts from blast furnace gas. The precipitation of these compounds has been achieved in other industries. For example, in the paper industry precipitators are used for the removal of sodium salts from furnace gases. Likewise, potassium salts are removed from cement kiln gases by a precipitator.

If there is excessive potash and sodium in the exit

gases it is probably due to particle size rather than chemical composition. Also, the wettability of these compounds may enter into the picture. About all that can be said on this phase is that if it is necessary to remove these compounds about the only way that it can be done is to provide equipment to secure a higher over all recovery to insure the removal of these finer or fumy particles.

Whenever water is used in steel equipment such as in a secondary blast furnace precipitator, there is always the question of corrosion. The amount and type of corrosion will depend on the nature of the water and the type of service. In general, there are two types of water used for this service which cause corrosion, namely, high acid content and high oxygen content.

In the case of acid waters, if the pH of the water ranges between 5 to 3 or lower, corrosion or pitting is bound to occur. The only recourse in this case is to treat the water so that its acidity is diminished, or to use corrosion resisting materials.

The other type of water is that containing excessive oxygen. In this case the weirs and tops of the pipes usually corrode. The corrosion seems to be localized at these two points—it seems as if the water flowing down the pipe loses its oxygen so that at the bottom of the pipe there is little, if any, remaining. In one particular case, the water fed to the precipitator had a dissolved oxygen content of 6.5 to 7 parts per million, whereas the effluent showed no O_2. Our engineer's belief in this case was that the O_2 united with the metal at the upper end of the pipes and the weir rings and also that it was displaced by CO_2 and CO from the blast furnace gas—the latter probably being the greatest source of O_2 depletion.

Several methods have been tried in combating this corrosion. In the first place, replaceable weir rings are now used instead of flared pipes, which were used in the original installations. This change has reduced the maintenance cost very appreciably. The use of copper bearing steels instead of mild steel was tried in one job but the results did not justify going to this particular metal—the loss per year was about the same as on the mild steel pipes.

Since most of the trouble has been encountered on the weir rings, attempts have been made to use different types of weirs. Cadmium plated weirs were tried without success. Chromium weirs now under test seem to give some promise.

On one job where corrosion was rather severe, it was found that the water, before going to the precipitator, was used in a condenser of the barometric type where aeration took place. The water, in this case, contained 9 to 11 parts per million dissolved oxygen and it was interesting to note that this water, before it was used in the boilers, was treated so that its O_2 content was .03 parts per million. On this particular precipitator we have stainless steel weir rings under test, which have been in operation about a year, and, according to reports from the customer, are standing up satisfactorily. Negotiations are in progress to equip a complete unit with this type of ring.

Since this corrosion is tied up with the water used and there are just as many types of water as there are steel plants, it resolves itself into a local problem. It has been suggested that the water be treated rather than use the more expensive type of corrosion resisting materials. Our company has done some work on this phase. At the Broken Hill Proprietary Company, Ltd., Australia, where high oxygen contents were encountered a series of studies were made to determine methods of combating this oxygen corrosion. Our engineer's report on this work is very interesting and a brief extract taken from his report reads as follows:

"To determine the effect of O_2 free water on the weirs, two adjacent nests of weirs were thoroughly cleaned of all scale and sand-papered until a bright surface was obtained. A pump line which recirculated O_2 free effluent from the precipitator hopper was connected to one of the cleaned sections and the ordinary raw sea water was allowed to flow over the other cleaned section. This condition was maintained for a 30 day continuous operating period after which the precipitator was opened for inspection.

"The condition of the weirs over which the raw water had flowed was found to be just as bad as it had been before they had been cleaned, but the weirs over which the O_2 free water had flowed showed practically no signs of corrosion except for a slight brown discoloration through which the bright metal could be plainly seen, indicating definitely that corrosion could be reduced to practically a negligible factor by the use of O_2 free water."

Answering Mr. Stubblefield's last question, in the early secondary blast furnace precipitators trouble was encountered with breakage of discharge electrodes near the top support. These failures can no doubt be traced to chemical corrosion and electrical erosion as Mr. Stubblefield states.

The design of the electrode support has been changed in the later jobs so that a compression type support of rather long bearing surface is used. This type of support insures good electrical contact and due to the fact that a larger electrode section is used the effect of corrosion is minimized. Since the adoption of this new type of support the number of failures of discharge electrodes has been greatly reduced.

L. C. EDGAR: I do not have much to say about the precipitator. My principal concern in the matter is to see if we can not approach the precipitator problem from the investment cost angle. The initial cost stays with a job forever; you always have that high investment charge. I think it would be well worth the time of those in the precipitator business to give a little more consideration to the possibility of reducing first cost, either by using a 12 in. tube or by some other means.

R. A. FIELD: What is the highest temperature at which you can clean gas by precipitation? Is it still necessary to cool gas in a cooling tower, or can you put it direct into the dust catcher?

L. M. ROBERTS: On precipitation problems, notably in sulphide ore roasting, precipitators have been used at temperatures up to 1150 degrees F. In this case, the temperature limitation is one of materials of construction and not of precipitating phenomena.

As discussed in the paper, precipitators have been successfully used on both ferromanganese and high silicon iron furnaces on raw furnace gas without scrubbing. Also, dry precipitators have been used for primary

cleaning on dry gas praticularly in the Birmingham district.

However, the greatest demand at the present time is for secondary cleaning in which the use of the water flushed tube has proved very satisfactory.

A. J. McDONALD: I would like to determine whether there is any nitric acid corrosion in a precipitator? Is there any possibility of the formation of a dilute acid of nitrogen due to oxygen in the water?

L. M. ROBERTS: Due to the corona breakdown of the gases, oxides of nitrogen are formed in a precipitator. However, the amount is usually very small and we do not believe there would be enough present to affect the acidity of the water or to cause nitric acid corrosion. Tests on a precipitator treating air indicated only negligible amounts of these compounds and we would expect less in the case of blast furnace gas where less oxygen is present. Generally, we have found no measurable increase in the acidity of the water after it has passed through a precipitator which could be attributed to acidic nitrogen compounds produced by the corona discharge.

J. D. JONES: From the answer you gave to the question as to a comparison between the 8 in. and 12 in. tubes, I take it in view of having a blast furnace gas of a certain cleanliness the 8 in. is the right one, and the 12 in. from there down. Has there been no development beyond those two phases?

L. M. ROBERTS: Based on the information we have available at the present time, we would specify the 8 in. pipe installation if a high degree of cleanliness were desired. If an outlet gas of low degree of cleanliness were desired, we probably would specify the 12 in. pipe if the designs were economical. As soon as use of the 12 in. pipe precipitator has been proven under actual operating conditions on blast furnace gases, it may be possible to change the specifications for its use.

R. H. SCHALLER: With the rapid adoption of electrical precipitation of blast furnace dust and with this ideal equipment for the purpose, we should progress one step further at this point and work on the recovery of potash to help reduce the cost of furnace iron.

L. M. ROBERTS: Precipitators have been used successfully in the removal of potash particularly in the cement industry. This use of such equipment is rather extensive, and is on a commercial basis. We do not know of any installation where the potash is removed from blast furnace gas for subsequent use, though the material precipitated from the ferro-manganese gas mentioned in the paper was relatively high in this compound. There is no reason why a precipitator could not be designed to remove potash from blast furnace gas if it should be desired and if it were economically practical to do so.

JAMES FARRINGTON: We have just completed an installation of an electric precipitator at our coke works to clean the gas, and all the equipment except the generating unit is in the main building with the saturators. The generating unit is in a brick building built in one corner of the main building.

We purchase our power for the coke works and are purchasing an emergency gasoline driven a-c. generator to supply power to the precipitator in case of failure of the purchased power, as the dirty gas would soon clog up the gas handling equipment.

I would like to ask if there have been any installation of electric precipitators to remove spelter from the galvanizing pot hoods and pipes and if so, is that an economical installation?

L. M. ROBERTS: There have been no commercial installations on the collection of fume from galvanizing pot hoods. We would expect that this would be a case of collecting zinc fume and oxide. There should be no difficulty in collecting this type of material since preicpitators have been used successfully on zinc bearing gases. The economics of the installation would probably be a question of local design and the volume of the gas to be treated. If the volume of gas per pot hood is relatively small, the chances for an economical installation would be enhanced.

H. RICHARDSON: I had an opportunity to go to India on a job we were just completing there. It consists of five 300-pipe units. It is a very fine installation, and is practically the same as we have in this country. They are using a still water supply, and material from the cooling towers and precipitators goes to a Dorr thickener and is recovered as a sludge to prevent pollution.

Incidentally, I might mention for the benefit of the blast furnace men, they have a better ore there, and get it to within one per cent of theoretical iron.

Improvements in GALVANIZING Plants and Practice

By NELSON E. COOK

GENERAL SUPERINTENDENT

GALVANIZING OPERATIONS

WHEELING STEEL CORPORATION

STEUBENVILLE, OHIO

Presented before A. I. S. E.

PITTSBURGH DISTRICT SECTION

January 15, 1940

▲ THERE are those periods, in the history of any industry, which are particularly outstanding because of unusual efforts and accomplishments. In the steel industry, the last decade has been such a period, and many improvements in design and practice have been made, which have practically revolutionized the industry. Galvanizing plants have endeavored to keep pace with these developments and, in some instances, the improvements in this field have exceeded the improvements in the general industry. This is due to the fact that there were probably more opportunities for major improvements in the field of galvanizing than in some other branches of the steel industry.

We must recognize the fact that, until quite recently, a typical galvanizing plant, whether for sheets, pipe, wire, or hand-dipping, was considered just one of those things in the steel industry which it was necessary to have attached to a steel plant, but which did not seem to be important enough to warrant any special consideration. Therefore, we find that old galvanizing units were located in some part of a plant which was not especially desirable or useful for anything else. We must also recognize the fact that there was a time, not many years ago, when a galvanizing department was practically a dumping ground, and when it was considered that the galvanizer could use almost any black material as a base for galvanizing which was not suited for any other product. These conditions, together with the fact that the average galvanizer either did not have at his command, or did not avail himself of, much scientific or technical information, made the problem of quality galvanizing a most difficult one. We have often heard the process of galvanizing referred to as the art of galvanizing. Truly, the old galvanizer who worked under such conditions, and who attempted to perform a process as difficult as is that of applying zinc coatings, was a real artist. Too much praise cannot be given to those pioneers in this industry, who, in spite of all these difficulties, worked as true artists and produced galvanized products which were of a rather consistent high quality. The old galvanizer eventually arrived at the correct solutions to most problems, the difficulty being that it took him a considerably longer time to accomplish this than with more modern methods now in common use.

Galvanized products represent a substantial percentage of the steel production in this country and, due to the fact that zinc is probably our best protective metal coating on steel, we anticipate that galvanized products will be used in greatly increasing quantities as time goes on, and as we are able to improve the quality of these coatings. Improvements have kept apace in all branches of galvanizing, but, since most improvements have recently been made in sheet galvanizing, we shall confine ourselves to a discussion of this phase of the subject in this paper.

In the sheet galvanizing industry there have been many essential improvements which have given the galvanizer the opportunity to meet new problems and new specifications.

First, and we believe very important, is the realization by the industry that galvanizing is a valuable process, and one worthy of special consideration. We now find that galvanizing departments are not just put away in some dark corner of a steel plant, but every effort is being made to modernize these plants, providing a good working space, good heating, ventilating, and lighting, and, in general, greatly improved working conditions. It is recognized that the quality of the final product in any plant will reflect the general conditions of that plant, and every effort is now being made by the industry to put such plants on a very high plane.

Secondly, we recognize that galvanizing is a very complicated, technical process, and we are endeavoring to remove as much of the guess work from this process as possible, by placing at the command of the galvanizer all the ability and skill of all branches of the engineering profession. We have long since realized that no individual department in a steel operation will progress very far by relying entirely on its own facilities and

personnel. Therefore, we are constantly encouraging the cooperation of the galvanizer with all other departments and, by taking advantage of this cooperation, we are now able to overcome many of those variables which made the galvanizing process such a complicated and even mysterious one.

There are several essential steps in the process of galvanizing sheets. It is very difficult to produce quality sheets unless all these steps are properly coordinated and controlled in a scientific way.

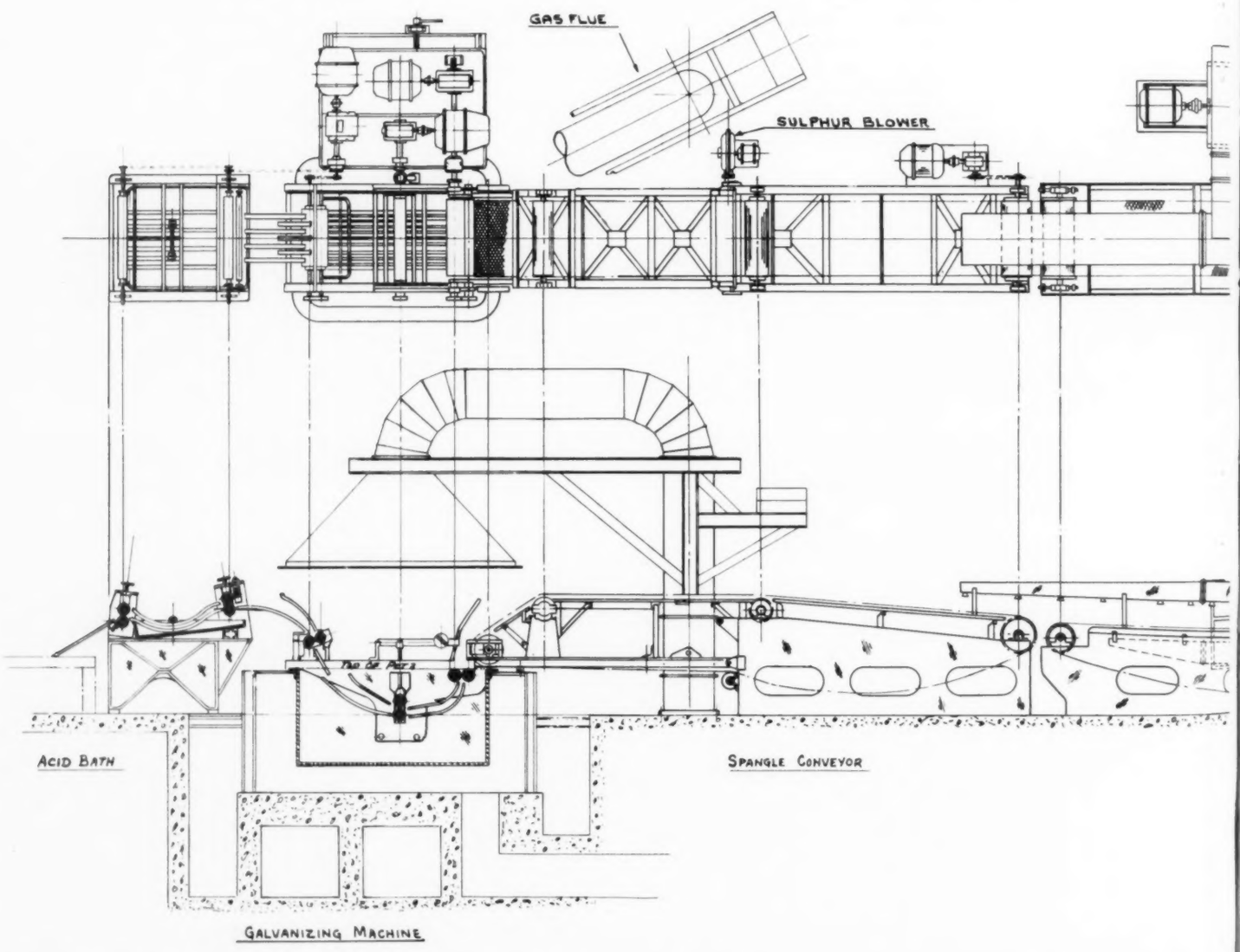
The first essential is the selection of the proper base sheet for producing the desired galvanized sheet. Instead of assuming that almost any type of base sheet would be satisfactory for galvanizing, as we did some years ago, we are realizing more and more each day that the proper selection of the base sheet is one of the most important steps in the process, and the galvanizer is now taking advantage of chemical and metallurgical knowledge, much of which was not formerly available to him. Especially is this important because, in the last decade, the steel industry has made great strides in producing new types of base sheets. Just ten years ago, continuous hot and cold reduced sheets were a novelty, but the industry has developed such sheets, in this short time, to a high state of perfection. These types of sheets introduced to the galvanizer many and varied new problems, and it has been necessary for the galvanizer to keep apace of this development. Many of these problems have been solved, and, with continued advancement in processing, we have no doubt but that we may expect many more innovations in the near future. In the problem, the galvanizer is now working very closely with chemical and metallurgical engineers, with rather remarkable results. What was considered almost impossible just ten years ago has now been, to a great extent, accomplished.

The second essential in the galvanizing process is the proper cleaning and preparation of the sheet prior to applying the zinc coating. This is a step in the process which has caused a considerable amount of trouble in the past. This trouble was caused by lack of suitable technical control, rather than by the complication of the process. In the days when almost any type of base sheet was delivered to the pickling department, there were such a variety of black sheets that it would have been almost impossible for any standard pickling process to have produced a good, uniformly cleaned product. Then, too, old pickling departments were not given the benefit of any scientific knowledge or control, and it is rather remarkable that such a good average job was done. However, galvanizers have realized for many years that the pickling department must be put on a scientific, controlled, basis, and very great improvements have been made, and are constantly being made throughout the industry in this phase of the problem. The introduction of the new types of continuous hot and cold reduced sheets has further complicated the pickling processes, and introduced problems in pickling which galvanizers have never before faced. We now have problems of oil removal in addition to scale removal. We have new types of scale, new types of surface, new types of annealing, and new types of grain structure, all of which are entirely new conditions for the pickler to contend with. We have new problems in hydrogen absorption, requiring the use of new types of pickling acid baths and agents, and we are even resorting, in some cases, to the use of steel grit blast cleaning in cases where the problems cannot be satisfactorily worked out with acid baths. The galvanizer knows that, in order to produce a properly coated sheet, it is necessary to deliver to the coating bath a thoroughly cleaned sheet, and one that is cleaned in such a way as to

General view of three modern galvanizing lines forming part of a recent installation.

produce, in connection with the right fluxing treatment prior to applying the zinc coating, a finished product which will meet the requirements at hand. Knowing the type of sheet that must be delivered to the coating bath, it is now a rather simple problem, with the help of chemical and metallurgical control, to set up a pickling or cleaning process which will meet the general requirements. Without such technical control, proper pickling and cleaning of sheets is almost impossible, and, although fair results might eventually be accomplished by the guess and try method, the product would not be uniform, and the cleaning could only be accomplished at the expense of efficiency in the use of equipment and materials.

The third essential in the galvanizing process is the correct application of the zinc coating to the sheet. It is in this phase of the process that a major portion of the improvements have recently been made. The galvanizing machine, or rig, is placed in a suitable, correctly heated, steel container, known commonly in the sheet industry as a pot or kettle. Essentially, in the coating operation, a sheet passes first through an acid bath, to complete the cleaning, then through squeezing rolls and then through flux rolls, which are mounted directly over the flux bath which covers most of the entrance end of the zinc bath. It next goes through suitably constructed and shaped steel guides to a set of driven rolls near the center bottom of the pot, then through another set of guides, and finally through a pair of driven exit rolls. These exit rolls are used to regulate weights of coating and are only partly submerged in the zinc metal bath. They are kept clean and free from oxides by the application of flux baths, through which these rolls travel, on each revolution, after contact has been made with the emerging sheet. There are many types and sizes of galvanizing machines,



some of them having multiple sets of bottom rolls, and some with other modifications which are simply mechanical modifications, designed to accomplish some particular purpose. It is at this stage of the galvanizing process that we introduce such a great variety of variables, all of which, either singly, or in combination, have a great effect on the quality and type of coating which is produced.

First, and one of the most important variables, is the control of the heating of the metal bath. Many types and applications of heating have been used, some of them good and some bad. There was a tendency, some years ago, to use the smallest kettles that could be conveniently used, for the reason that small baths were supposedly more economical of operation, and also for the reason that coatings, some years ago, were constantly made thinner and thinner, in which case small equipment is sometimes advantageous. However, during the last decade, galvanizers have constantly developed heavier and tighter coatings. We have also proved that small equipment, from an economical standpoint, in heating, is not practical. There are other considerations which make the problem of heating important. In the galvanizing kettle there is a continual formation of what we term dross metal, which is a combination of zinc with a percentage of iron, which iron comes from the sheet, the kettle, or the machine. This metal, being heavier than zinc, at the temperature of operation, settles to the bottom of the kettle, in an efficient operation, and is periodically removed. It is essential to anticipate this formation of dross metal in designing the furnace of the kettle, and, in order to obtain proper kettle life, it is necessary to protect as much of the bottom of the kettle as will contain dross from direct heating, otherwise disastrous conditions may result. There are certain essentials in heating a metal bath

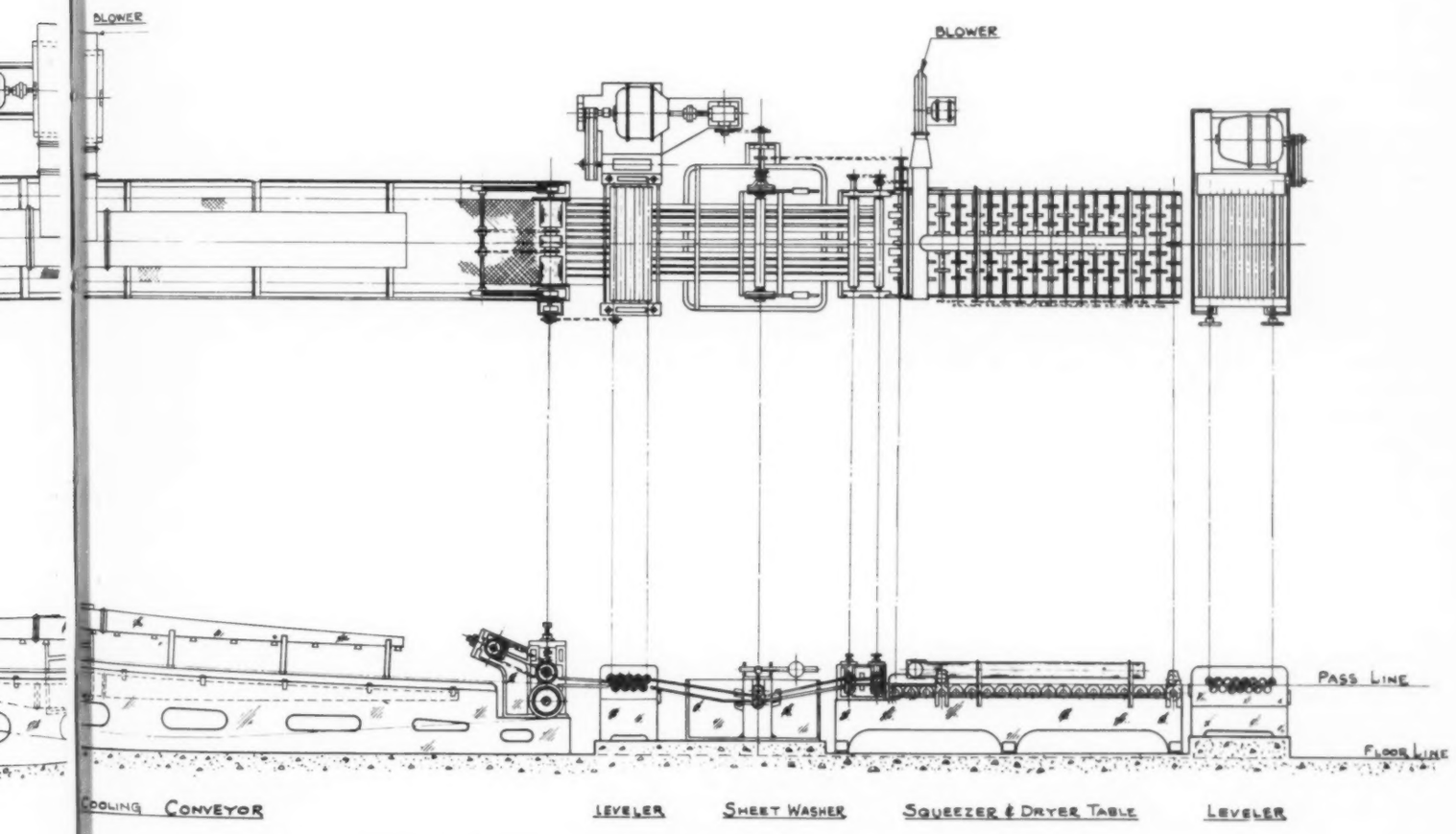


FIGURE 2—Diagram showing 50–58 in. galvanizing line, using single bottom roll. This line is about 103 ft. long, with a speed range of 13.5 to 135 ft. per min.

which must be followed closely in order to produce a good product. The installation should, of course, be economical. Heat should be so controlled as to be constant at any desired temperature, and the installation should be flexible enough to satisfactorily cover a wide range of cold work tonnage input. The furnace must provide for proper distribution of heat throughout the kettle, bearing in mind that, while we desire uniform temperatures in the bath, the work which enters the pot is cold, requiring the greatest heat input at that point. Most important, it is necessary that heat be applied to a galvanizing bath in as gentle and soft a manner as possible, in order to prevent any hot spots which would result in agitation of the metal in the bath. Undue agitation of the metal keeps the dross metal continually in suspension and this is especially undesirable, since it is the aim of the galvanizer to apply as pure a coating of zinc as possible. A coating which contains too much dross metal is not of a high quality.

When approached in a systematic way, the problem of heating a galvanizing kettle is not a difficult one. It remains only for the galvanizer to determine how much cold work he wishes to pass through the kettle in a given time, what ranges of speed he wishes to use, what range of temperature he expects to use, and what quantities of dross he expects to form in the bottom of the kettle during such periods as he may determine. Knowing these things, and knowing the types of fuel available, the combustion engineer is then able to determine definitely just what size of heating area is required, and what size of kettle is required to accomplish the desired results. With this scientific knowledge, the galvanizer, in following these recommendations, will be able to accomplish what he desires, and will be able to control rather definitely one of those variables which has caused so much trouble in the quality galvanizing of sheets. Many worth while improvements in this phase of the process have already been made and will be constantly made in the future, all of which tend to better quality in galvanized sheets.

Secondly, the correct mechanical operation of the driven rolls in a galvanizing machine is most important. Some of the equipment used by the industry has been very light, and methods of driving rolls, in many cases, have been far from satisfactory. We do not mean to infer that this equipment has not been good, or that it has not answered the purposes for which it was intended and applicable. Such is not the case, and we believe that there will always be some need for this type of equipment. However, it is recognized that the most certain way to make a uniform sheet is to coat it in a galvanizing machine which has a smooth and steady driving mechanism. Many of the problems of the galvanizer have been caused by the improper timing of the several sets of rolls in the machine. This problem was further complicated, especially in old style, single drive machines, in which all rolls were driven from one motor, by the fact that the different sets of rolls could not possibly be maintained at the same diameters, necessitating complicated gear changes on these various rolls in order to get any semblance of synchronization of the speeds. In this type of equipment, even if rolls are substantially synchronized at the start of an operation, a certain subsequent alloy build-up on the bottom rolls will cause an unbalanced speed between the bottom rolls, and the exit and flux rolls. This lack of synchronization causes a dangerous tension or buckling of the product, especially on longer sheets, and oftentimes results in uneven or damaged coatings. Depending on the type and degree of unbalanced synchronization of these rolls, we may get either buckling of the product or serious guide scratches. In either case, lack of synchronization causes agitation of metal in the coating bath, which is not desirable. These are very important considerations, since the durability of a galvanized sheet depends on the even, continuous distribution of the zinc coating. The industry has made many recent improvements in overcoming these difficulties. There are two important methods for synchronization now in common use. The one system synchronizes the drive mechanically, with multiple motors. The newer system is that providing for positive synchronization of the rolls by positive, variable voltage, electric control, employing multiple motor drive. Both systems are more costly than the old system of single motor drive, but both are good, and both are well worth the additional cost in order to provide more uniform coatings. Even old types of equipment and drives have been given considerable attention by the industry in recent years, and very marked improvement has generally been made in this phase of the operation.

Thirdly, there are other variables in this part of the galvanizing operation which have been, to a great extent, overcome with chemical and metallurgical assistance. It is rather surprising the number of types of steel and other metals which are used in the construction of a galvanizing machine. It is very important that the galvanizing machine be constructed of correct materials, not only for the purpose of providing longer life for the machine itself, but also for the purpose of providing the materials, in the machine, which will, in no way, interfere with the proper bonding of the zinc coating to the base sheet as the sheet passes through. Galvanizing rolls have probably caused more troubles to the galvanizer than any other part of the machine. Bad galvanizing rolls, which cannot be operated and maintained efficiently, are responsible for many badly coated sheets. But much progress has been made in the past few years in establishing standards for this part of the equipment and the results, in every case, have indicated better quality of zinc coatings.

Fourth, there are variables in the galvanizing operation which must still be controlled by the galvanizer, himself, and these may be referred to as the art which a galvanizer practices. Knowing the type of galvanized sheet he wants to produce, and knowing the other conditions that go to make up the entire process, the galvanizer determines the alloys and types of alloys, methods of fluxing, and all other conditions which he should employ to attain his end. This is very specialized knowledge which a galvanizer may use to vary the types of coatings, and to produce widely different results as desired.

Summing up the improvements which have been made in the actual application of zinc coatings to sheets, we find that developments of recent years have, without any doubt, been instrumental in producing better galvanized coatings. Primarily, we have recognized the complications of this process, and have eliminated as many of the variables as possible. The old galvanizer

of many years ago, faced innumerable problems with, very little assistance in overcoming them. He had all the variables of pickling various types of sheets, of unknown quality, without much help in the way of control. He had countless variables in the coating operation itself. It is remarkable that he produced such good sheets under conditions where the variables changed so often that, just about the time he thought he had one under control, several others would suddenly get out of control. The recent developments have tended toward scientific control. We now have better control over black product, we have technical control of pickling operations, we have provided adequate and controlled heating, and we have provided as positive and as mechanically perfect a galvanizing machine as possible. With these variables under rather positive control, it is now possible for the galvanizer to concentrate on the fewer remaining variables, and, under such conditions, he cannot help but accomplish more than he formerly did.

We have heard much recently of "high speed galvanizing." This term is meaningless when used in a general way. We have always had high speed galvanizing and slow speed galvanizing, depending on the type of product we wished to produce, and the galvanizing equipment available. There is no such thing as a high speed operation, applicable to all types of products. After all, speeds of galvanizing are very definite functions of material and equipment, and there are very well defined metallurgical limitations to which we must work. In coating a sheet with zinc, an alloy layer of zinc and iron forms next to the steel base, which layer is between the steel base and the outer coating of substantially pure zinc. As we have mentioned previously, this zinc-iron alloy layer is brittle and it is desirable that it be held to a minimum in order to provide tight coatings. Naturally, the quicker we can pass a sheet through the coating bath, other things being equal, the thinner this layer will be. At the same time, we must regulate our speeds so that the coating will be as evenly distributed over the surface of the sheet as possible, and these speeds, therefore, must be functions of such things as type of sheet, type of pickling, size of equipment, and temperatures of operation. In modern installations, where the heating of the bath can be controlled definitely within wide limits, where the machines can be smoothly driven within wide ranges of speed, and where dross formation and deposition can be very well controlled, the galvanizer can, without doubt, increase speeds of coating. When this modern equipment is used judiciously by the galvanizer, he is even able to produce better coatings at these higher speeds, than with the older equipment.

We shall now consider a part of the galvanizing operation which has been given special attention during the past few years. When a sheet emerges from the coating bath, it is necessary to properly treat it or cool it in some satisfactory way before taking it through the final inspection. It is at this point in the process of making galvanized sheets that many variables may be introduced which will change the physical and chemical characteristics of the final product. As the sheet emerges from the coating bath, it is at a temperature of approximately 800 degrees F., and the sheet has very definite characteristics which have been determined by the type of black base sheet, type of pickling, length of travel in the bath, temperature of the bath, chemical composition of the bath, and the speed of travel through the bath. The coating, on its first emergence, is still in a molten condition, and many processes may be introduced at this point which will entirely change the characteristics of the finished product. Most of these processes have to do with differences in degree and speed of cooling, which produce many and varied types of finishes. The ordinary type of galvanized sheet, with which we are all familiar, is the one which has a flowery or spangled appearance. This spangled appearance may be varied almost at will, by varying conditions such as type of zinc used, and method of cooling the coated sheet. Even when using the same type of zinc in the galvanizing bath at all times, it is possible, by varying the methods of cooling, to determine and define the type of spangle. For example, we are all familiar with the ordinary sheet which is very bright in appearance, and is characterized by alternate bright and dull flowers of irregular size and shape. This type of spangle is termed "black and white" spangle, and is produced by rather rapid cooling of the sheet when it emerges from the coating bath. It is possible, by varying the method of cooling, to obtain, from this same sheet, coated in the same bath under the same conditions, an appearance which, while still spangled, will be very dull and flat in appearance, with a much less degree of contrast in the spangles or flowers. It is also possible, from the same sheet, to obtain an appearance in which the spangles are semi-uniformly or uniformly formed. This type of sheet is commonly known as a controlled spangle sheet. It is also possible to obtain, from the same sheet, a finished product which is absolutely free from the spangled appearance. This is accomplished by any one of several methods, usually having to do with controlled cooling of the molten coating, most of which methods are patented processes and do not warrant discussion in this paper. All of these methods have their application in producing a variety of types of galvanized sheets, each of which has some definite merit for some particular type of specialized work. However, the common type of galvanized sheet is the one which is spangled in some manner, and this type represents, and will continue to represent, the great majority of galvanized tonnages. During the past few years much progress has been made in producing galvanized sheets for special and for new uses. Never in the history of galvanizing did the customer have so many types of product available from which he might choose some particular sheet for his particular use, than he does at the present time, and developments in this phase of the work are continually going forward.

In the production of ordinary galvanized coatings, much thought has been given by the galvanizer as to what takes place between the galvanizing bath and the inspection table. The ordinary layman might suppose that it is only necessary to cool the sheet before it reaches the inspection table, so that it might be conveniently handled in inspection. However, much depends on the type of cooling of the sheet at this stage of the process, as to the degree of quality which is obtained in the final product. Many good galvanized coatings, which have been correctly produced in all previous stages of the process, have been lowered in quality by

improper cooling, because, in cooling a coated sheet, we are dealing with a complicated metallurgical process, and we must treat it as such. As we have mentioned previously, a galvanized coating consists, essentially, of two layers of coating on the steel base, the top layer being substantially pure zinc, and the middle layer, or layer next the steel base, being an alloy of zinc and iron. The top or pure layer is relatively ductile, but the zinc iron layer is relatively brittle. The thickness of the alloy layer determines, in a large measure, the type of cooling which should be used. In general, where we have a relatively thick alloy layer, it is not good practice to cool the sheet too rapidly because of the fact that such quick, non-uniform cooling will tend to loosen the coating, making it undesirable as a manufacturing sheet. When we have a relatively thin alloy layer, it is possible to cool somewhat quicker without damaging the quality of the tightness of the coating. In general, also, quick cooling of a galvanized sheet produces a bright spangled appearance, while slow cooling tends to dull the spangled appearance.

Much progress has been made in producing black sheets in the past few years, and the galvanizer now has at his command several types of sheets, all of which may be treated in different ways, and all of which will produce different final results. These types of sheets range from the old sheet mill or jobbing mill hot rolled sheet, to the present day cold reduced material. Each type of sheet, coming through the same identical coating bath, will be coated with a different type of coating, structurally. Some sheets will produce relatively thin alloy layers, and others will produce relatively thick alloy layers, under the same coating conditions. Therefore, it is now extremely important that the galvanizer have a very flexible cooling process, in order to economically take advantage of all of these types of sheets.

There are as many types of cooling systems, or run-out systems, as there are galvanizing plants. The old system was simply to convey the sheet on two, three, or four chains for some determined distance, which, in most cases, was only from 15 to 30 ft., blowing air on the sheets in some manner as they passed along the chains, then conveying them through a roller leveler, and possibly over porcupine wheels to the inspection table. In some cases the distances were varied, and the position of the units of the equipment in the line was varied. The total length of the cooling system varied within wide limits, which limits were sometimes deliberately calculated, but more often were dictated by the space made available in a plant for the galvanizing department. As a result, each producer of galvanized sheets provided the best equipment possible for the type of product he desired to make, and for the amount of space available.

The modern system, which is now being used to an increasingly greater extent, is to provide a very long run out, using some form of conveyor belt as the carrying medium for the sheet. This conveyor belt is provided with uniform cooling on both top and bottom of the sheet, and the degree of cooling can be varied at will with simple control. The conveyor belt, itself, can be used or not, as desired, to form a modified controlled or uniform spangle. When so used, the conveyor belt, which extends as close to the exit rolls of the galvanizing machine as possible, runs over magnetized rolls, which are set close to the front of the conveyor belt. The sheet falls on this conveyor belt while the coating is still molten, and is held to the belt by the magnetized rolls. Since spangles will form quickly at any point of contact of the molten coating with cold metal, it is possible, in this way, to form a rather uniform spangle, the size and shape depending on the type of conveyor belt used. After the sheet travels along the conveyor belt for a predetermined distance, and when it is sufficiently cooled, it is sometimes put through a water cooling bath, through a drier, and then through a good roller leveler. Of course this procedure may be varied as desired. The essential thing is to correctly cool any type of sheet so that when it reaches the inspection table it will be practically at room temperature. We should bear in mind that there is nothing essentially new in most of this modern equipment, or nothing new in any combination of units of equipment in the line. However, what we have done, in recent years, is to so improve all parts of this equipment, mechanically, that we can now determine and install a complete system which is flexible enough to take care of all types of sheets that we produce. With the new system of variable voltage synchronized control which is used to drive the galvanizing machine, we can now combine all of this cooling system with the same control, thus synchronizing the entire unit from the feeding end of the galvanizing machine, to the inspection table. With such a positive control system, in which all parts of the production line are operating under the most favorable conditions, we are now able to eliminate many of those troublesome variables with which the old galvanizer had to contend, and we are able to produce quality coatings on more types of black base sheets.

The uses to which galvanized sheets are put have been increased many fold in recent years. They are used for purposes in which maximum life of the product is most important. There are sheets in which appearance is the important factor. There are sheets in which the major requirement is in forming the material with a minimum of flaking of the coating. There are sheets which are required to be processed so that they will be applicable to further processing, such as painting. The specifications on these and many other types of galvanized sheets have been gradually made more exacting, and other new specifications will come to be introduced which will require further research on the part of the galvanizer. Just as in the manufacture of any other product, the galvanizer has not yet found the magic key to the making of perfect material. But we believe all will agree that the galvanizing industry is making a conscientious effort to solve most of the problems presented to it. The steel industry has recognized, more than ever before, that galvanized products represent an important part of the industry as a whole, and the industry has been very generous in making available to the galvanizer the means with which to improve his product. Progress in any line of endeavor must be made in a sound, scientific way, if it is to be of value. It is necessary to determine the weak points in any operation, and to endeavor to correct them where possible. The galvanizing industry is no exception, and it is on this basis that the industry is making important improvements. The important starting point in an operation is to provide good quarters, with good heat-

ing, lighting, ventilating, and working conditions, all of which tend to improve quality of product. This is being rapidly accomplished. The next step is to provide very flexible, controlled mechanically sound, equipment. This is being done by the industry. And, finally, it is important to make available to the galvanizer technical and engineering knowledge. This is being done. With all of these things accomplished, the galvanizer can now devote his time more than ever before to the actual technique of the coating operation, and this is quite enough to occupy any galvanizer's time. All of these things, when properly coordinated, cannot but be productive of better quality galvanized coatings.

Truly, sheet galvanizing plants are gradually growing up and are assuming their rightful place in the steel industry.

DISCUSSION

PRESENTED BY

R. L. ALLSHOUSE, *Sales Engineer,* Aetna-Standard Engineering Company, Youngstown, Ohio.

R. J. WEAN, *President,* Wean Engineering Company, Warren, Ohio.

R. E. O'BRIEN, *Assistant Superintendent,* 93 in. Cold Strip and Galvanizing Department, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

NELSON E. COOK, *General Superintendent,* Galvanizing Operations, Wheeling Steel Corporation, Steubenville, Ohio.

FREEMAN H. DYKE, *Superintendent,* Blooming, Bar and Hot Strip Mill, Wheeling Steel Corporation, Steubenville, Ohio.

D. O. FISHER, *Superintendent of Galvanizing,* American Rolling Mill Company, Middletown, Ohio.

MATT WILSON, *Manager,* Sheet and Tin Plate Department, Bethlehem Steel Company, Sparrows Point, Maryland.

F. J. O'BRIEN, *Superintendent of Galvanizing,* Carnegie-Illinois Steel Corporation, Vandergrift, Pennsylvania.

W. F. McGARRITY, *Chief Metallurgist,* Carnegie-Illinois Steel Corporation, Irvin Works, Dravosburg, Pennsylvania.

HAROLD P. GAW, *Senior Metallurgist,* American Rolling Mill Company, Middletown, Ohio.

GILES SYDNOR, *Assistant Superintendent,* Sheet, Tin and Strip Mills, Bethlehem Steel Company, Sparrows Point, Maryland.

R. L. ALLSHOUSE: Mr. Cook has very nicely pointed out the major improvements in sheet galvanizing practice and the many reasons for the improved results achieved to date. These reasons can be roughly summed up in one word—cooperation.

In no other branch of the steel industry can such complete cooperation be pointed to. The chemical manufacturers who provide the pickling, cleaning and fluxing agents, the zinc producer who make the spelter and alloys, the steel mill metallurgists and engineers, the galvanizers—all combined their efforts to produce a better galvanized sheet and more economical product.

Not many years ago, galvanizing was considered a deep, dark secret and often the equipment manufacturer did not know how his product was being used. What worked successfully in one plant would not work at all in another.

With the present exchange of knowledge and ideas, the machinery builder has been able to help the sheet galvanizer solve many of his problems and even anticipate to some extent his future requirements. The galvanizing industry today is a healthy one, and thereby subject to constant change.

Mechanical improvements have been rapid in the last few years. Galvanizing machine drives have changed from simple gear connections to modern engineering developments weighing ten tons or more, which assure smooth chatter-free operation through greater speed ranges. Variable voltage control eliminates manual gear changes, and mechanical variable speed transmissions provide positive stepless control to all of the galvanizing rolls from a single source of power. Thus, all outside variables are eliminated and the operator has positive control of the various sets of rolls while the machine is in operation, should changing conditions in the pot cause the rolls to become out of synchronism. This method of synchronizing the rolls while in operation has recently been patented. Only through positive synchronization of the coating rolls can extremely long sheets be galvanized without buckling or chatter. The conveying, cooling and leveling equipment has been improved as well, and the operator has complete control at his finger tips. Simplicity of design and control is the keynote for the mechanical engineer.

The galvanizing industry has thus become of age and is rapidly making still greater place for itself within the steel trade. The mechanical engineer and equipment manufacturer are striding along with the galvanizer to produce still better galvanized sheets. Newer and larger markets will undoubtedly be developed with benefits to all within the steel industry.

R. J. WEAN: The Pittsburgh district section of the Association of Iron and Steel Engineers is quite fortunate in having a presentation on galvanizing by Mr. Nelson E. Cook, for I know of no other individual who can speak with equal authority on this subject. Mr. Cook comes from a family of experts on galvanizing, and the modern plant which was installed recently under his supervision is an indication of the confidence his company has in his knowledge of the subject of galvanizing, a process about which very little written information of an authoritative nature is available.

What Mr. Cook says as to the general attitude of steel plant managers up until recent years is unquestionably true. Galvanizing departments were considered more as a necessary evil than as a profitable venture. However, the multiplied demand for many new uses of galvanized products and the very large tonnage that is produced has altered their opinion, and today many of the largest producers have or are contemplating complete modernization of their galvanizing departments.

There are many instances in which a better quality, and as much as 100 per cent increase in production, can

be brought about in a galvanizing department by modernization. This can be accomplished without any increase in man power.

I do not wish to recite the mechanical improvements that have been made in a complete galvanizing line, as many of these things are entirely familiar to you. However, it would be well to point out that the multi-motor drive, whereby a separate motor is used for driving each set of rolls, is probably the most noted mechanical, in combination with electrical, improvement that has been put into galvanizing practice; and, it is also fitting that the first complete galvanizing department equipped in this manner should be under Mr. Cook's direct supervision.

This new system of driving, or, let us say, the newer system, is where all motors are fed by variable voltage from a common motor generator set, and speed variations are obtained by varying the supply voltage. Synchronization for different size rolls is obtained by slightly varying the speed of the individual motors by field control. This type of drive conforms to the advanced electrical control practice used on high speed strip mills and other applications where speed control must be positive and accurate and the relation of one set of rolls remain positively constant with another set.

The control of zinc-iron oxide growth, as well as spangle formation while cooling, has not been given proper attention in past years, but, as pointed out in the paper, is now being given the proper attention; and, this has resulted in a superior product from the standpoint of coating adherence, as well as salability of product.

Another part of the galvanizing process which has been receiving a great deal of study and on which a great deal of development work has been done is the production of galvanized sheets with an extremely tight coating. This development has followed the theory of passing the sheets through a pre-heating agent and then passing them through a shallow zinc bath, there being a minimum of contact between the zinc and the pre-heating agent. This results in the formation of a very thin zinc-iron alloy and a very light coating of spelter, having a quality of adherence not procurable in an ordinary galvanizing pot. A number of these units are in operation, and the apparatus and method involved are the subject of pending patent applications in the United States Patent Office.

Before closing, it might be well to state that, in all probability, many galvanizing departments could improve their operations by giving more attention to the pickling and washing operations before the sheets are passed into the galvanizing bath.

It is my belief that the proper washing or scrubbing of the sheets after pickling and directly before entering the galvanizing bath will save money for sheet producers and raise their percentage of prime sheets, for it has been found that the salts and sponge iron that adhere to the surface of the steel when coming from the pickling bath can be removed by washing, and that this will materially cut down the amount of these iron salts carried into the bath. These salts are responsible for a large part of the dross formed in a pot, and it is only common sense that, if they are held to the minimum, there will be economy and improvement in the operation.

R. E. O'BRIEN: We appreciate Mr. Cook's paper very much. He has covered the equipment very thoroughly. However, Mr. Cook mentioned as the first requisite the base metal, but there has been very little said about that. I would like to hear what Mr. Cook has to say as to the recommended control of the base metal which is to be used for zinc coating.

NELSON E. COOK: I would like to answer the question in this way. First, I like the word cooperation which was used a while ago. In determining the type of base sheet to use, it is necessary for us to first determine the type of sheet which best suits all our other galvanizing conditions, such as pickling, fluxing, coating, etc. Since there are such a variety of equipments, treatments, and base sheets, the determination of the best base sheet to use is quite naturally an individual problem with each mill. However, when such type if determined, every effort should be exerted to control the base sheet, metallurgically. This is where the cooperation enters the picture. It is a fact that, in the past, there has always been a fence put up between different divisions of a plant and different functions of a plant. At one time there was a fence between chemists and metallurgists. Certainly there was a big fence between the metallurgists and the galvanizers. There was a time when they hardly knew each other: in many cases they did not care to. This condition has existed throughout the steel plant, in some cases even to the point where one division was continually trying to put something over on the other. There must be actual cooperation. The problems must be thoroughly discussed. The galvanizer must tell the metallurgist what his limitations are, and certainly the two can eventually get together on some type of sheet which will give the desired results. First, determine the type you want, and, that being done, there should be no difficulty in getting proper metallurgical control, within workable limits.

R. E. O'BRIEN: Should the galvanizer be given a certain grade of steel for a certain type of product? Should the rolling temperature, percentage of reduction, and annealing temperature be thoroughly controlled, or should he get as soft a sheet as it is possible to make? We have been trying to equal a hot rolled sheet when using cold reduced sheets.

NELSON E. COOK: There are various ways of answering this question. I believe, however, that we are approaching the problem in the wrong way if we deliberately try to make a cold reduced sheet match a hot rolled sheet in all qualities. If you try to make a cold reduced sheet absolutely match a hot rolled sheet, you have quite a problem on your hands. I have heard of processes which might approximate this condition, but I believe that costs of extra processing might be prohibitive. Are we not assuming the wrong attitude when we try to make the cold strip sheet match the hot rolled sheet? Are we all convinced that the hot rolled sheet is the answer to all problems, and that, therefore, any new product must match it? I see no reason for assuming that the hot rolled sheet is a perfect sheet. We know that cold reduced material has a lot of advantages and a considerable number of disadvantages. It, therefore,

becomes the problem for the galvanizer to work out with the metallurgist, to the best advantage of his particular set-up, and to the best advantage of his company, the particular type of sheet necessary. What might be suitable as a product for sale for your company, might be entirely different than a product for sale for our company. In approaching the problem in this way, with a broad outlook, it is entirely likely that somewhere along the line we will find advantages to the new sheet, provided we do not always assume that we must try to match a sheet mill product.

F. H. DYKE: Mr. Cook spoke about the numerous variables in the process. The galvanizer has learned so much more about galvanizing than he previously did that all the mills can do to give him better control is to pick out a standard of uniformity on both hot rolled and cold reduced sheets and stick to this standard as closely as physically possible. This practice eliminates some of the variables.

D. O. FISHER: No doubt big improvements have been made in galvanizing equipment; but the biggest improvements have been made in the base sheet produced for galvanizing, and metallurgical control of processes in producing steel suitable to coat. Also, managements' interest in the galvanizing field is shown through the purchase of the latest equipment and the processing practices in making better steel for coating.

MATT WILSON: I was impressed with the engineer's idea of equipment. There is one thing lacking, however. One thing might be said on the art of galvanizing. We can have synchronized machinery and proper cleaning and cooling; we have those factors in every shop. But management and supervision constitute the art of galvanizing. No one can tell you the art. If we are given the equipment, all those other things are taken care of.

I would like someone to answer a question. I notice in modern equipment they still have the leaded zinc. Why do we have to have equipment which reduces the galvanized tonnage if tight coatings can be made otherwise? Yet, on every hand, the greatest stress is put on savings.

NELSON E. COOK: You refer, I believe, to the use of the combination pot. This type of lead zinc pot is a valuable installation, and will continue in use for some time, we believe. The purpose is to make a light coating, and a coating free from the usual heavy alloy layer, which is brittle. Tonnages are also reduced in order to make light coated front ends of sheets, in addition to the generally lighter coatings, since such sheets are used for very hard jobs. I think you have in mind that, since we now have high speed equipment, well regulated heating of baths, etc., all of which tend to produce coatings, at high speeds, with greatly reduced alloy layers, why do we not discard the use of lead zinc pots and make tight enough coatings on the new equipment, and at greatly reduced costs when compared with the slow running lead zinc equipment. This is a good question. However, the answer is simple. It is a fact that, with high speed, in the new equipment, we do greatly reduce the alloy layer. But, it is true in any equipment, that high speeds will result in heavy front end coating, and when we are trying to make an extra tight coated sheet, which must be fairly tight over its entire length, the heavy front end condition is very serious. It is apparent that, for a real tight coated sheet, the coating should be uniform, light, as free as possible from alloy layer, and, in ordinary type galvanized sheets, this can still best be accomplished by lead zinc pots. We still use some of the old combination pots in one of our plants.

F. J. O'BRIEN: One question came to my mind. Mr. Cook made the statement that there was an advantage in cold-reduced sheets. I would like to know what he had in mind.

NELSON E. COOK: There is one big advantage that I see to cold reduced sheets, which appears to be rather important. All other conditions being equal, in a galvanizing operation, we should obtain, from a cold reduced sheet, assuming that it is properly cleaned, a tighter coated sheet. The cold reduced sheet has a smooth, dense, surface, and this is very conducive to very light alloy layer formation, which is quite important in considering the tightness of coating on any sheet. As to whether or not cold strip can be successfully used to take the place of materials which were formerly specified on a sheet or hot rolled basis, I do not believe we have yet had enough experience to answer definitely. However, we have no reason to believe that they will not be so used. We also have no reason to believe that such sheets may not be better, in some cases, than the old style sheet, for it is entirely possible that the properties of the cold sheet, while considerably different from the properties of the hot rolled sheet, may be advantageous for many uses, with the proper development and promotion. We do believe that cold reduced sheets, if and when they are approved for any purpose, can be made more uniformly and consistently than hot sheets.

W. F. MCGARRITY: Inasmuch as Mr. Cook predicted that cold reduced base galvanized sheets would have a tighter adherence than hand mill product, it would be interesting to have an opinion as to what effect shot-blasted rolls have on the tightness of coatings.

NELSON E. COOK: At the present time we are not favorably inclined to artificial roughening of sheets by blasted rolling. We are now working along the lines of taking care of the situation in pickling treatments. It is impossible to suggest means of treating sheets in a general way, because each steel plant has its own individual cleaning problem, which is governed by its methods of rolling. What would be satisfactory in our plant would probably have no bearing at all on your problem. We are sure of one thing, and that is, when you are using a pickling treatment on cold reduced sheets, it is absolutely necessary to have complete cooperation of the galvanizer, metallurgist, chemist, and cold mill superintendent, if anything at all is to be accomplished. Without this complete cooperation, treatment of cold reduced material for coating, in a satisfactory way, is almost impossible.

H. P. GAW: I wish to thank Mr. Cook for the paper which he has just presented. There are many interesting things brought up. In connection with a question asked on the coating of cold reduced sheets, it seems to me to

(*Please turn to page 45*)

QUALITY PROBLEMS *in the Operation of* WIDE STRIP MILLS

By G. D. TRANTER
General Superintendent
AMERICAN ROLLING MILL COMPANY
MIDDLETOWN, OHIO

Presented before A. I. S. E. ANNUAL SPRING CONFERENCE, Cincinnati, Ohio, April 1 and 2, 1940

▲ THE development of the continuous rolling process has made possible the economical manufacture of sheet products, resulting not only in improved quality and performance in existing fields, but in opening up new avenues leading to greater uses for iron and steel sheets.

The principle of cold reduction, with its resultant fine grain, followed by high-fire box annealing to give the necessary ductility, has produced physical properties which have enabled the sheet manufacturer to keep pace, at least in some degree, with the ever-increasing demand for improved drawing and forming qualities.

G. D. TRANTER

The inherent qualities of steel can be bettered by making the open hearth department an integral part of the continuous process of sheet manufacture.

The sheet surface produced by the modern continuous mill is far superior to that produced by former methods of rolling, and rejections on the inspection table today show fewer defects than were accepted on prime sheets of even a few years ago. The continuous rolling process has not only made it possible to manufacture a greatly improved product, but also has resulted in lower cost products to the consumer.

The modern continuous mill with its auxiliary equipment is a very efficient tool; yet despite its many fundamental advantages certain details of practice can go "haywire" and the plant finds itself in a quality slump with high rejection losses on the inspection table and poor performance in the fabricating plant. The successful operation of the continuous rolling process requires constant vigilance and attention to even the smallest details.

Many of the older operations serving the continuous mill take on a new significance in their effect upon the quality and performance of the ultimate product. The quality of steel made in the open hearth, attention to soaking pit heating, slabbing mill practice, and other operations that have been in existence for many years and had reached a high degree of perfection when measured in terms of former requirements, now present new

and varied problems having an important bearing on results obtained by this modern method of sheet production.

STEEL QUALITY

Despite the flexibility of the open hearth process, the continuous mill has brought about refinements in steel making heretofore considered very desirable but not altogether an absolute necessity. Closer analysis limits, very narrow ranges in teeming temperatures, greater accuracy in predetermining the correct deoxidation, together with utmost attention to the mechanical aspect of ladle and mould practice, are very essential factors from the standpoint of preventing basic defects arising from interior blowholes, or scabs and cracks visible on the ingot surface. Many of the metallurgical problems in the open hearth originate at the blast furnace, therefore pig iron analyses and casting temperatures must also be taken into account.

The manufacture of quality steels in the open hearth for sheet purposes is a subject in itself and cannot be covered in detail within the scope of this paper. Suffice it to say, the inherent qualities of the steel have a far greater effect on rejection losses and the performance in the press room than is generally recognized; therefore the open hearth must be made an integral part of the continuous process of sheet manufacture when considered in its broader sense.

In many of the quality problems arising in the sheet business, we are very prone to suspect some unusual phenomenon or mysterious source. We are apt to ignore the real cause, in our daily round of the department, by failing to note some small detail of practice, or a combination of details of the more or less "homely" variety.

For instance, the soaking pit foreman complains about having more than the normal amount of stool stickers on heats from the open hearth. He is looking at it entirely from the side of inconvenience and delay in charging his pits. However, his statement is significant and, other things being equal, it would indicate that teeming temperatures in the open hearth were higher than usual with the possible danger of increased difficulty with skin blowholes in the ingot. While the optical pyrometer on the pouring platform serves as a check on steel temperatures, nevertheless the general range can gradually tend toward hotter steel with its attendant dangers. This example is cited merely to illustrate how a practical observation may serve as the clue to some quality problem.

SOAKING PIT HEATING

Following the making of steel, soaking pit heating is a factor of extreme importance. Its chief influence is on the surface quality of the product. Poorly heated ingots give rise to surface cracks or snakes on the slab surface, exposure of ingot blowholes which would otherwise be of no serious consequence, and further results in poor cleaning of scale through the slabbing mill.

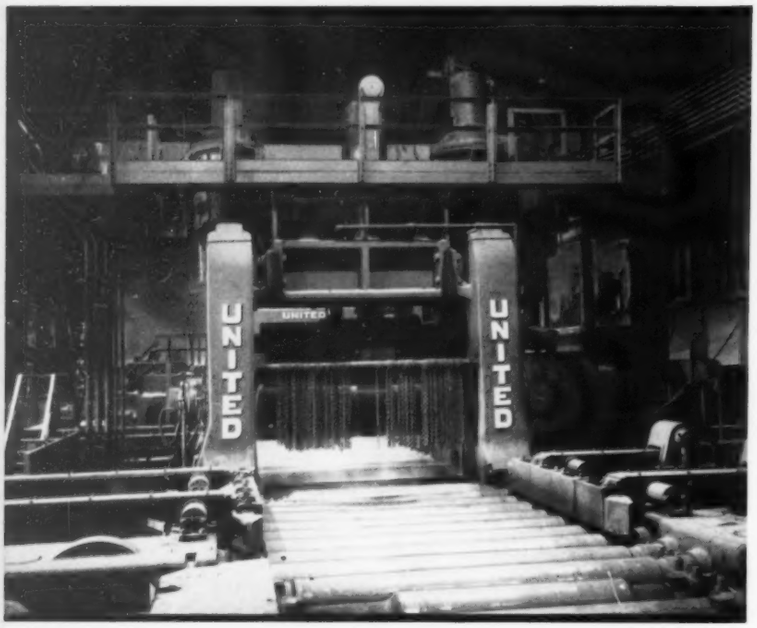
Soaking pit temperatures vary with different grades of steel, but in any case the ingot should be well and uniformly soaked to the predetermined temperature throughout. Atmosphere and temperatures are of major importance, and the use of combustion control equipment, together with pyrometers, is very desirable from the standpoint of uniformity. The human element should not be overlooked in this respect as the heating operation cannot entirely be a matter of automatic control.

The performance of the ingot in the slabbing mill is a criterion of the quality of heating delivered by the soaking pits; and where temperature readings made after the first pass and the last pass denote an abnormal drop, a lack of uniform heating is indicated. An ingot properly heated and soaked will very rapidly recover the surface heat lost through the chilling action of the rolls in the slabbing mill. Where the surface heat returns too slowly, because of lack of uniform heating, the colder surface tends to break or crack and does not heal or close up during subsequent passes. The type of scale jacket, usually an indication of the heating qualities, should readily free itself from the ingot in the mill and not cling to the surface to cause rolled in scale.

EQUIPMENT

Factors affecting the quality on continuous mills may vary because of differences in engineering layout, types

Soaking pit heating is a factor of extreme importance, having its chief influence on the surface quality of the product. Temperatures vary with different grades of steel, but in any case the ingot should be well and uniformly soaked throughout.



This slabbing mill is designed for broadside rolling, so that the entire ingot may be slabbed for subsequent reduction into one continuous coil.

of product, fuel, or other local conditions. Special attention may have to be focused on certain equipment in one plant because of its limitations whereas it may be of no serious consequence in another.

Regardless of the type of equipment or its arrangement, it is important to keep in mind that the practice must be developed to suit existing conditions. The practice in one plant cannot always be identically duplicated in another and may vary in some detail. However, there are certain basic principles involved that are fundamental, and apply to any of the several types of continuous mills now in operation.

Proper scheduling is an important consideration where the process is continuous from ingot to coil with no intermediate interruption between the slabbing mill and the hot strip mill. In this case, even with the multiplicity of grades used for various requirements, tapping schedules in the open hearth must be geared up to slabbing and hot strip mill operations in the proper sequence. Extreme changes in gauges and widths from one order to the next or mill delays are not conducive to good quality and smooth operations; consequently the scheduling must take into account the necessity for having hot steel available from the soaking pits and through the slabbing mill when roll conditions in the strip mill are suitable for rolling the ordered width and gauge. A system of scheduling has been developed to a surprisingly high degree of efficiency and is disrupted only by very unusual conditions.

ROLLING PRACTICE

The subject matter of this paper deals primarily with the factors affecting quality on the type and layout of the continuous hot strip mill at the Middletown Division of the American Rolling Mill Company. The engineering layout and features of this mill have been described in a previously published article (IRON AND STEEL ENGINEER, March, 1940), so it will not be necessary to interpret them in detail in this paper.

The hot strip mill at the Middletown Division was originally built as a 58 in. mill, and when the engineering layout was made it was the widest mill of its type in existence. It was designed with the idea of ultimately widening the mill to use 72 in. rolls. However, it has actually been rebuilt and widened to use 80 in. rolls producing a maximum width of 75 in. in the hot strip. The roughing stands have been re-arranged and re-spaced to accommodate a longer piece, and one four-high stand was transferred from the roughing train and added to the finishing train. The present arrangement of the roughing mills consists of three two-high stands and two four-high stands, the finishing mills consisting of six four-high stands. With the former set-up, the length of the coil was greatly limited, which necessitated welding several coils together for rolling on the cold strip mill. The new slabbing mill, with the re-arrangement of the roughing and finishing stands in the hot strip mill, was designed for rolling up to a 15,000 lb. coil from the present size ingot, or larger, if the ingot size is increased.

The new layout not only has provided for a heavier coil, but the longer coil has made possible more ideal rolling conditions on the cold strip mill and subsequent processing. Yield losses along the line have been greatly reduced, and the shape and gauge variation of the cold reduced strip has been considerably improved.

The new slabbing and edging mill at Middletown combines flexibility with a very satisfactory method for rolling slabs, and since the slab width is obtained by spreading on the horizontal mill, it is possible to roll the product of an entire ingot into one coil. The operation of the mill is comparatively simple, the spreading being accomplished by turning the ingot on the table, either ahead of the horizontal mill, or between the horizontal and the vertical mill, and broadsiding to the desired slab width. In cases where very little spreading is required, it may be accomplished by "cornering" instead of a full 90 degree turn.

In spreading, the thickness of the ingot is first reduced approximately 25 to 30 per cent by straightaway rolling. This requires about three to five passes, and is followed by at least two edging passes which serve to close up and toughen the surface on the edge of the piece, also to avoid internal ruptures. It requires about four to six broadside passes to spread a 57 in. ingot out to a 74 in. wide slab. After broadsiding, the ingot is again revolved on the table and rolled straightaway to the ordered slab thickness using the proper combination of flat and edging passes.

The increased time element of the spreading operation is negligible, only a few extra seconds being required to turn the ingot on the table. However, ingot sizes have

been worked out to provide the least degree of spreading with the idea of better utilization of the slab furnace capacity.

Five ingot sizes are used, all of which are of the same thickness, *viz.* 20 in. The widths are 30, 36, 42, 50 and 57 in. Except for cases where an off-grade heat is diverted or where ingots are taken off the bank for small orders, very little spreading is done below 56 in. wide. The 57 in. size is used for all slab widths above 56 in. up to 75 in., this being the capacity of the strip mill.

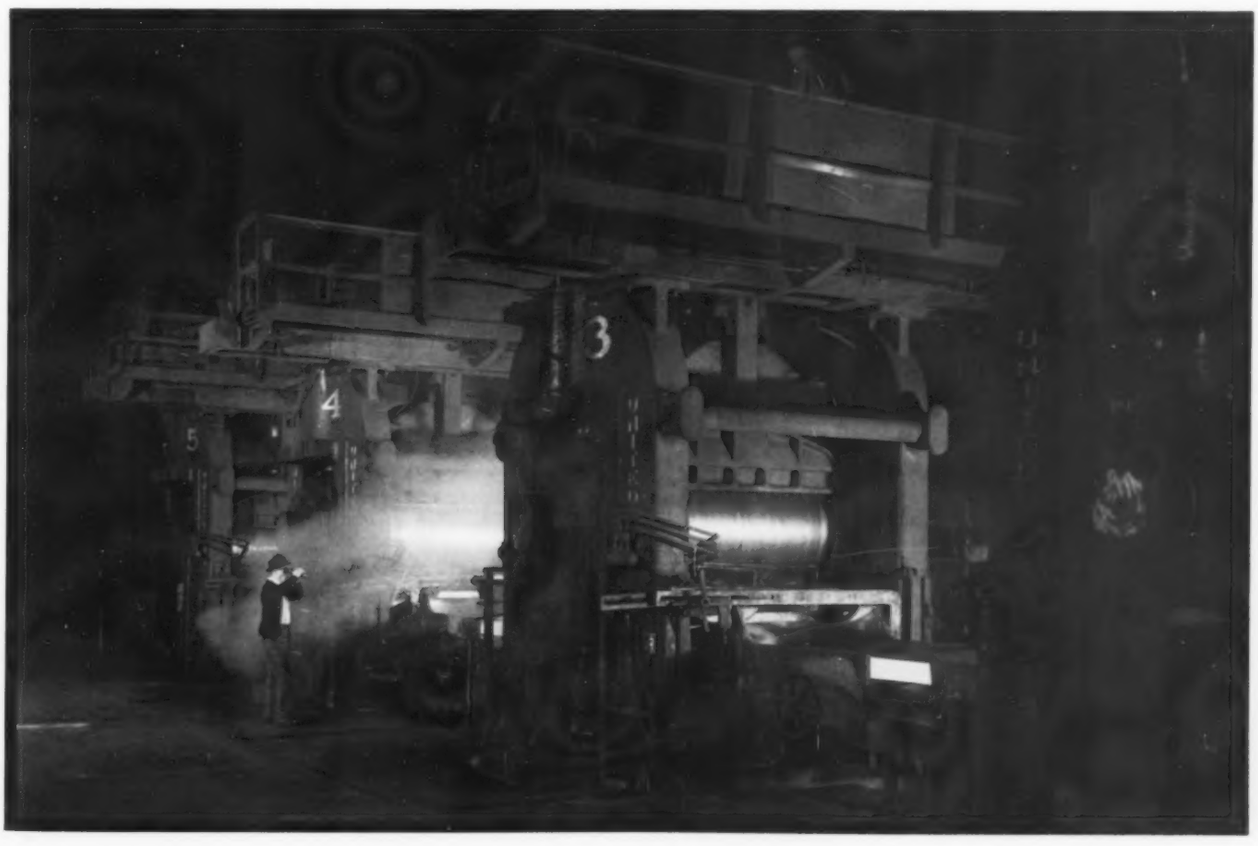
When the new slabbing mill was originally built, the pass line of the horizontal mill was three inches above the table line. Considerable difficulty was experienced, with a tendency for the slab to "turn down," causing some delay in revolving for broadsiding and also causing excessive shock on the table rolls.

This was corrected by lowering the mill 1½ in., after which little difficulty was encountered except where the condition would originate from a lack of uniform heating.

Where considerable cooling water is used on the slabbing mill rolls, it is advisable to use wipers or water shields to protect the surface of the hot piece from excessive chilling by the cooling water running off the top roll. Hydraulic sprays are used just ahead of the edger to de-scale, since the ingot is not flopped or edged in the vertical position. The spray is used only when the piece is traveling away from the horizontal mill, thus permitting the surface to recover its heat before the next pass. This prevents cracking the slab surface, sometimes called "surface check," and is usually most pronounced in low metalloid material. If the sprays are not properly manipulated, this "checked" condition will carry through to the finished sheet and results in light scabs and slivers.

SURFACE CONDITIONING

From the slabbing mill the hot slab is transferred to a high line table where the surface is hot scarfed. The operating principle of the scarfing machine consists in an instantaneous preheating operation when the piece first engages the "head" on which the burners are mounted. A mixture of six parts of oxygen to one part of acetylene gas is used for preheating and when the cutting starts, the mixture is automatically changed to twenty parts of oxygen to one part of acetylene. The depth of penetration is controlled by the gas pressure (40 to 50 pounds) and the speed of the table, usually 130 to 150 feet per minute. Hard-surfaced ribs welded to a set of shoes maintain a fixed distance between the "floating head" and the piece, thus making it possible to follow any irregularities in the flatness of the slab. The slab is turned over and the operation repeated so that both surfaces are scarfed. Following the scarfing operation the slab is again transferred to another table where it is cropped and divided depending on the desired weight of the finished coil.



This finishing train was originally built as a 58 in. mill, but was designed with the idea of ultimately widening the mill to use 72 in. rolls. It has now been rebuilt and widened to use 80 in. rolls, producing a maximum width of 75 in. in the hot strip.

SLAB HEATING FURNACES

The slabs from the shear proceed on the high line table where they enter one of three slab furnaces arranged to accommodate a full length slab up to 29 feet long. Slab furnace heating has a most important bearing on the surface qualities of the hot rolled strip, and proper heating is a function of time, temperature and furnace atmosphere.

Slabs on which no scarfing is done enter the furnace at approximately 2000 to 2050 degrees F., while scarfed material is 50 to 75 degrees cooler. The charging zone of the furnace is held at 2350 degrees F. and the discharge of the furnace is held at 2350 degrees F. and the discharge zone approximately 2400 degrees F., depending on the type of steel being heated.

An average of 20 to 24 minutes is required to reheat the slab to the proper condition and desired rolling temperature, and may vary depending on the grade of steel and the amount of heat lost between the soaking pit and the slab furnace. Scarfed material is necessarily held in the furnace about three minutes longer due to the extra heat lost in manipulating the slab during the scarfing operation.

A well soaked slab is just as important as a well soaked ingot, as gauge control, drafts and finishing temperatures are dependent upon a uniform temperature in the piece. Furthermore, a poorly heated slab may cause mechanical difficulty due to wrecks, cobbles, roll breakage, etc., in the mill.

The furnace atmosphere should promote the formation of a scale having the proper characteristics with respect to thickness and ease of removal during rolling through the roughing stands. The furnace atmosphere in the charging zone of the furnace is held as neutral as possible, whereas the discharge zone shows about three to five per cent excess oxygen. Where the scale thickness is controlled between certain limits (.050 to .060 in. in our case) the surface of the strip is improved, particularly with respect to light slivers which may adhere to the slab prior to reheating in the slab furnace. The scale thickness on hot scarfed material will run slightly less, usually .045 to .055. The scale thickness referred to in the foregoing is for mild steel since the carbon content is a controlling factor, other things being equal.

STRIP MILL ROLLING

Descaling through the roughing stands has an all-important influence on surface qualities. Sufficient hydraulic pressure is necessary which in most cases is 900 to 1,000 pounds at the nozzle. The sprays should be so located with respect to the various roughing stands to permit the piece to recover its surface heat before a subsequent pass in the next mill. Air scaling must also be taken into account and removed as formed, otherwise it will be rolled into the bar surface and show as a mottled scale pattern on the finished strip.

The hydraulic system must be first class in all respects to incorporate a continuous flow of water with no stoppage of pipes, valves or nozzles to cause scale streaks or rolled in scale that carry through to the finished sheet. The mechanical phase of the hydraulic system should provide for the proper type of nozzle, positively operated valves, together with the necessary pumps, accumulators, and strainers to insure a constant supply and pressure.

In localities where the water supply contains organic matter or other ingredients which may cause clogging or stoppage of lines, it may be necessary to "blow out" the hydraulic system at frequent intervals, or to periodically "open" the lines to maintain the flow during week-end shut downs.

In addition to the proper installation and maintenance of the hydraulic descaling system, scale from another cause may be troublesome. This refers particularly to scale drag usually caused by a scratch ending up in a small ball of scale on the strip surface. A rough bottom guide, stuck table or looper roll is usually the cause of this defect.

The importance of the operation of the roughing stands on the shape and surface qualities of the finished strip cannot be under-estimated. Gauge variation, camber, variation in width, lack of flatness and various types of surface defects often result from certain rolling conditions in the roughing train.

Excessive drafts, and failure to provide for a proper system of roll changes, both backing-up as well as working rolls, particularly in the last two roughing mills, give rise to shape and gauge difficulties which cannot be corrected in the finishing stands.

Fire-cracked rolls have been the subject for much discussion with respect to the origin of light slivers and seams on the finished strip. In the writer's experience, certain types of slivers have been traced directly to fire-cracked rolls in the first and second stands of the roughing mill. In many cases these defects are extremely light on the finished sheet surface; however it has been necessary to reject such sheets because of the possibility of light slivers "opening up" when subjected to severe draws.

The question may arise as to what degree or extent fire-cracked rolls may be permitted. This may be answered by the results of a rather exhaustive test, wherein lead strips were passed through various degrees of fire-cracked rolls, thus making an imprint of the roll surface. The fire-cracked surface of the rolls was correlated with the final sheet inspection and the results indicated that a surprisingly small degree of fire-cracking would cause surface difficulty.

Proper rolling conditions on the finishing stands depend upon a number of factors: alignment of the mills, keeping the piece in line with proper entrance guides, and proper tension between mills by maintaining the correct relationship between drafts and speeds through the various stands, are among the more important. Roll surface in the finishing train is also very important as rough surface on the early stands leaves a pronounced pattern on the finished strip, while scars arising from tail marks, pinchers, etc., on the last stands may result in corrugations at some later stage of processing.

Speed and drafts must take into account gauge and size to be rolled, flexing of the rolls, power on the mill, finishing temperatures, all of which depend on the entering thickness of the piece. Irregularities in shape and gauge, cambered strip and wrecks on the mill all result

from failure to take these factors into consideration when setting up the mill prior to rolling an order. A system of scheduling the mill should be set up which provides for rolling the wider material following roll changes and "coming in" on the width gradually until another roll change becomes necessary. Radical changes in widths or gauges should be avoided.

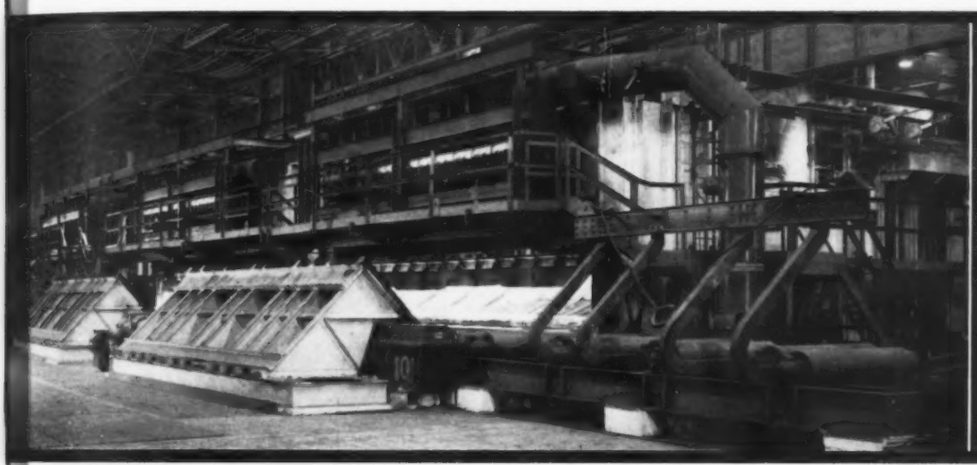
Shape defects may not always be noted in the hot rolled strip; in some cases such irregularities may cause shape defects to develop in some latter rolling operation. This is particularly true of light "pinchers," or where the tension between mills stretches the band, causing a "necking in" or narrow section in the width of the strip usually in the center of the coil. Corrugated patches or streaks, sometimes discovered after temper passing have been traced to "near pinchers" and undue stretching of the hot rolled band.

Maintenance of guides, chutes and loopers is an important quality consideration and periodic rebuilding of such equipment in the shops is recommended. One of the fundamental principles of rolling strip is to keep the equipment in line from one end to the other. Rigidity of the guides and proper alignment are necessary features in this respect as flatness and prevention of camber are not possible where the strip winds and twists through the mill.

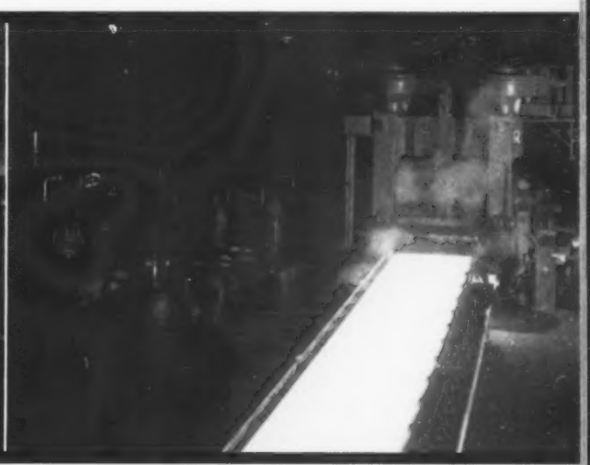
Maintenance of strip mill equipment is a very essential feature of a quality product, particularly with the emphasis on preventive maintenance. Where a machine reaches a productive rate of 175 to 200 tons per hour, even a comparatively short period of operation with defective equipment can result in many tons of damaged product. Scratches, gouges, and other forms of mechanical damage can be the cause of a surprisingly high percentage of rejections. Preventive maintenance is based on a systematic method of inspection and repairs during schedule shut downs, thus obviating delays and breakdowns during operating periods.

Finishing temperatures of the strip out of the last stand have an important bearing on the metallurgical qualities of the final product. Again no set rule or definite temperatures can be established for every plant. Analyses of the steel, degree of subsequent cold reduction, and processing must all be taken into consideration. Suffice it to say, the hot rolled strip should possess a uniformly normalized grain structure directly out of the mill and be cooled sufficiently so that the coiling temperature will not promote grain growth.

Where large coils are made the coiling temperature may be low enough to prevent grain growth, however in many cases the temperatures may be high enough to promote the formation of a scale or oxide extremely difficult to pickle, particularly in some sections of the strip. This results in slowing the rate of speed through the pickler. To avoid this the hot strip is usually cooled considerably below the temperature actually required for physical properties. Shower sprays or hydraulic sprays over the runout table, and close up to the mill, are usually installed for this purpose.



Slab furnace heating has a most important bearing on the surface qualities of the hot rolled strip, and proper heating is a function of time, temperature and furnace atmosphere.



This view shows the steel emerging from the roughing train and passing over a delay table en route to the finishing stands.

COILERS

The author of one of the early papers covering hot strip mill operations made the statement that rolling the strip was one problem but getting rid of it was another. This is certainly a true statement, especially so today where the length of strip to be disposed of is considerably more and the delivery speed much faster than on some of the earlier mills.

The strip mill superintendent is still searching for a coiler that can be depended upon under all conditions. Of course mill practice, coiler maintenance and skill of the operator are all important, nevertheless from an engineering and mechanical standpoint there is much to be desired.

Two types of coilers are in general use, the down coiler and the up coiler, the terms obviously describing

the direction and method in which the strip enters the coiler.

There is much to be said both pro and con on the relative merits of the two types. Telescope, scratches and coiler gouges are periodic difficulties experienced by most strip mill operators; but a discussion of coilers is a subject in itself and a highly controversial one at that.

METALLURGICAL CONTROL

The rapid increase in the production of sheet steel through the expansion of continuous strip mills has brought about the development of new application and uses for the product covering a wide range of metallurgical and physical requirements. The product of the hot strip mill has an important bearing on the physical properties of the finished product.

Adherence to standard methods is very important and to keep the practice in the "groove" the metallurgical staff in conjunction with the operating supervision and management set up a practice that is based on very complete data correlating various details of manufacture with results on the inspection table and performance in customers' plants. When a practice has been agreed upon and produces satisfactory results, it is important that no unauthorized deviations occur. Failure to observe even some apparently insignificant detail may cause poor results.

The metallurgical department is charged with the responsibility of noting any deviations from standard practice and to promptly direct such cases to the attention of the operating departments. Metallurgically trained observers working in the capacity of quality checkers are placed in every department. In the slabbing, bar and strip mill the observers cover such elements as heating conditions in the soaking pits, drafts on the slabbing mills slab furnace practice with respect to temperatures and oxide, temperatures through the mill, on the runout table and into the coilers. They also report such conditions as poor cleaning of scale, mechanical damage to the strip surface, and any other details affecting general surface or metallurgical properties.

The success of the plan depends on proper understanding and cooperation between the metallurgical staff and the operators, otherwise the system becomes a fault-finding process and fails to accomplish the desired purpose.

The plan has worked so successfully that the operators are constantly using the staff to check results and unearth quality difficulties that are bound to arise from time to time. Most of the difficulties can be corrected immediately, while others may require additional study and experimental work on the part of the entire metallurgical staff.

The plan of metallurgical control described in the foregoing is an important factor in maintaining standard practice through the various operations, and results in a high degree of uniformity in the finished product.

A very important feature of metallurgical control is the establishment and maintenance of a system that gives a complete history of every shipment, beginning with the open hearth heat through every operation and into the customer's plant. Every detail of practice and its effect on the ultimate performance in fabrication is thus available and very useful in further improving the product.

PERSONNEL

Technical literature in the main has dealt with the personal equation in a more or less abstract manner. The human element is a very important factor affecting ultimate results. Even with the best of equipment, efficiency is largely dependent upon the knowledge and technique of the personnel.

The best results are attained where the organization receives constant and intensive training in standard methods and practice based on the best available knowledge. The training program should also incorporate the safety features of the work as well as technique and operating practice. A well-organized training program, consistently carried out, coordinates the work, teaches strict adherence to standard practice methods and promotes uniformity of results. Wasteful practices are held to the minimum and the members of the organization are constantly reminded of the effect of their particular workmanship on results as a whole.

To be effective, the training program must be practical and deal with specific items of practice and subsequent results. Group conferences, individual instruction by the foreman, together with frequent review and explanation of standard practice methods will materially assist in developing a highly-trained personnel.

CONCLUSION

The emphasis which has been placed on the quality requirements of the hot rolled strip should not be construed to infer that all of the defective material at the inspection table has its origin in the slabbing mill and hot strip department.

The hot strip department may feel at times that they are in the position of having to transform variability from the open hearth into uniformity for the cold mill. However, through proper cooperation and working arrangement between the open hearth and slabbing mill departments, the effect of certain types of defects originating in the ingot can be greatly minimized. Where the mill receives prompt notification of certain characteristics with respect to the behavior of the metal during teeming, added precautions may be taken and special treatment given in heating and rolling.

Likewise, close contact with the cold strip department will focus attention on small troubles before they develop into larger ones and thus correct quality difficulties, before any large amount of defective material gets into the system.

The practical application of this plan wherein the steel works, the hot strip rolling and cold reduction units are brought into closer relationship has resulted in a large degree of success from a quality and performance standpoint.

DISCUSSION

PRESENTED BY

F. H. DYKE, *Superintendent*, Blooming, Bar and Hot Strip Mills, Wheeling Steel Corporation, Steubenville, Ohio.

C. L. McGRANAHAN, *Assistant General Superintendent*, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

F. H. DYKE: I want to compliment Mr. Tranter on his well prepared and extremely interesting paper. He has covered the ground so thoroughly there is little else to be brought out, and we merely wish to emphasize some of the points he has made.

A few years ago in the rolling of sheets, our main interest was making a pattern sheet, a sheet reasonably close to gauge and size and surface good enough to get by; but today the term pattern sheet is as extinct as the dodo.

The competition and demands of our customers in recent years have halved gauge and flatness tolerances. Modern shearing equipment has made size tolerances extremely difficult to meet by those who do not have this modern equipment. Surface requirements are such that it takes a well-trained man to differentiate at times between a hot rolled and cold rolled sheet. Some drawing requirements are such that on first inspection one would deem a sheet of lastex more suitable to make the part than a sheet of steel. Shipping specifications have not been neglected in the rush for better quality, and the specifications for packaging and loading are many and complex.

These factors make it absolutely necessary that every phase of steel making from the raw material down be minutely supervised if our rejections are not to be completely out of line and our performance records poor. Uniform soaking to the correct temperature is essential, both in soaking pit and reheating furnace practice.

Many defects are very difficult to detect in the slab, particularly when the slabs are conditioned with the scale on. They are only visible if the slab is pickled. Of course pickling can not be done in ordinary practice. These small defects at times follow through to the finished product and I think every operator has spent days tracing a defect down in his mill that eventually proved to come from a point in the operation previous to the time he got the material. Much bad surface also can be traced to copper and tin content.

The effect of segregation on flatness and gauge variation has often been overlooked. Particularly in the lighter gauges this can be a serious source of trouble. There are a lot of metallurgists that don't think this has a lot to do with it, but particularly on 18 gauge and 19 gauge hot rolled segregation can give us a lot of trouble.

As Mr. Tranter has said, constant vigilance is necessary and a complacent attitude when things are going smoothly may involve one in trouble which will take the entire organization a long time to correct.

C. L. McGRANAHAN: I am especially happy to concur with the statements made toward the end of Mr. Tranter's paper, calling for cooperation between the metallurgical and operating end, rather than having the metallurgical department acting as a fault-finding organization. There is frequently jealousy between them and it is a condition which should not be encouraged. Also I feel a great deal can be accomplished by a closer cooperation between the open hearth department and the strip mill operating department.

COOK DISCUSSION

(Continued from page 37)

be largely an individual plant's problem. The practices developed for one plant will not necessarily work in another plant, nor will the same grade of steel. Every department involved in the production of any particular grade of sheet needs to know the problems of the other units. Starting with a common understanding of the requirements, the cooperation of all will result in developing a steel and processing which will be satisfactory for that particular plant. The experiences of others can be very helpful, but after all, the practice used must be developed based on one's own conditions.

GILES SYDNOR: In your illustrations, you show a single and a double roll unit. I assume they are for different purposes. Can you tell me some of the things that govern your thought in adopting these two units? What are the advantages of the double roll, or why the extra bottom roll? Are there any operating efficiencies, or particular purposes? We do not have any such bottom roll installation.

NELSON E. COOK: This is our first double bottom roll equipment, and we have not yet had any experience with it. However, we are quite sure of the results we will get. We are using the double bottom roll equipment for gauges from No. 8 to 18. These gauges have always been made with too slow a speed, in most cases because of small pots. To properly galvanize, it is necessary for the sheet to come up to the temperature of the coating bath, and this is definitely governed by gauge, speed of travel, and size of bath. We have approached the problem in a rather scientific way. Knowing that speeds of running heavy gauges could be considerably increased without any harmful results, we have determined sizes of kettles necessary to accomplish the desired results at these increased speeds. In increasing these pot sizes, and lengths of travel, the necessity for double bottom rolls as a conveying mechanism is obvious. We believe that, on heavy gauges, we will be able to approximately double our outputs when compared with the smaller, single bottom roll equipment, with corresponding savings in cost. Our single bottom roll machines have speed ranges of 20 to 160 ft. per min., and our double bottom roll equipment has ranges of 11 to 99 ft. per min.

GILES SYDNOR: In these larger units, so called high-speed, in general, they call for a larger kettle installation than the old type kettles. In general, does it improve the dross loss? Is heating any easier, that is, is it a more uniform proposition in these larger kettles than in smaller kettles?

NELSON E. COOK: That is absolutely true. With the larger pot, it is easier to maintain a uniform temperature, and dross losses are improved.

ELECTRON TUBE CONTROL
for Steel Mill Application

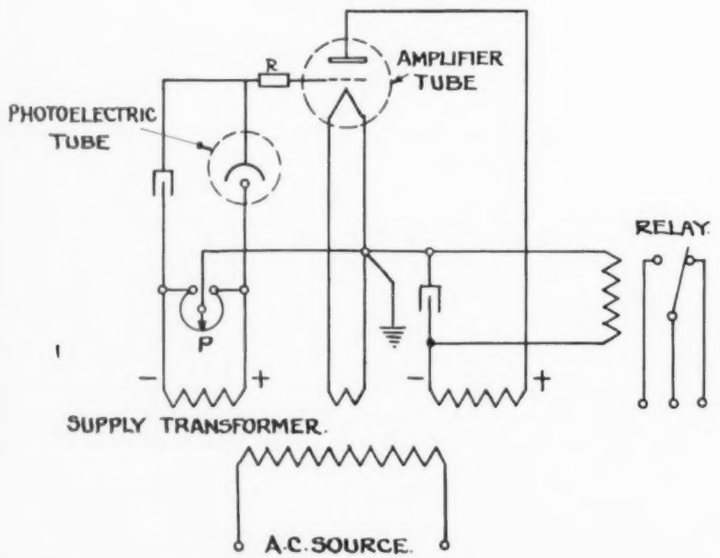
By H. L. PALMER
and H. W. POOLE
INDUSTRIAL DEPARTMENT
GENERAL ELECTRIC COMPANY
SCHENECTADY, NEW YORK

Presented before A. I. S. E. ANNUAL CONVENTION, Pittsburgh, Pennsylvania, September 26-29, 1940

▲ WHEN electronic control was first introduced for industrial applications, it was looked upon with considerable distrust by some and heralded as a cure-all by others. As one might expect after ten years of development, both of these schools of thought are wrong. Electronic control is not a cure-all for anybody's troubles, but it has proved that it has a definite place in industrial plants.

Electron tubes and electronic devices find their greatest application in the field of communication, especially in radio; and while in the field of communication electronic devices are indispensable and are, in many cases, the essential element around which the other equipment is built, in the industrial field electron tubes are relative new comers and in many cases are in competition with previously established lines of equipment.

FIGURE 1—Diagram showing amplifier circuit connections of a simple a-c. photo-electric relay.



For this reason progress in the application of electronic devices to the problems of industry has been less rapid than in the field of communication. The large scale production of electron tubes in the communication industry has to a certain extent made competition possible and permitted the use of electronic devices for industrial purposes, as otherwise their high developmental costs might have prohibited their use.

The application of electron tubes and electronic systems to industrial problems may be divided into two general groups: (1) those in which the electronic devices perform operations for which no other reasonably suitable apparatus is available, and (2) those for which conventional apparatus already exists. The dividing line between what may be called competitive and non-competitive applications, of course, cannot be clearly defined. In certain cases photo-electric devices, for example, have no strict competition from previously existing apparatus. On the other hand, electron tube equipment for supplying adjustable voltage to direct current motors is competitive with other apparatus and must be so considered from a standpoint of performance and economy.

Those jobs which are being performed satisfactorily with conventional methods of magnetic control should not be disturbed just for the sake of applying tube control. Surveys show that there are plenty of places where outstanding savings in material and labor as well as an improved quality of the product are possible and in such cases electronic control may be the tool to use. However, we should not lose sight of the fact that it must be applied intelligently and particular attention given to the tie between the tube control and the machine or process. For example, it is useless to provide a control which is responsive to a thousandth of an inch for use on a machine which is not required to

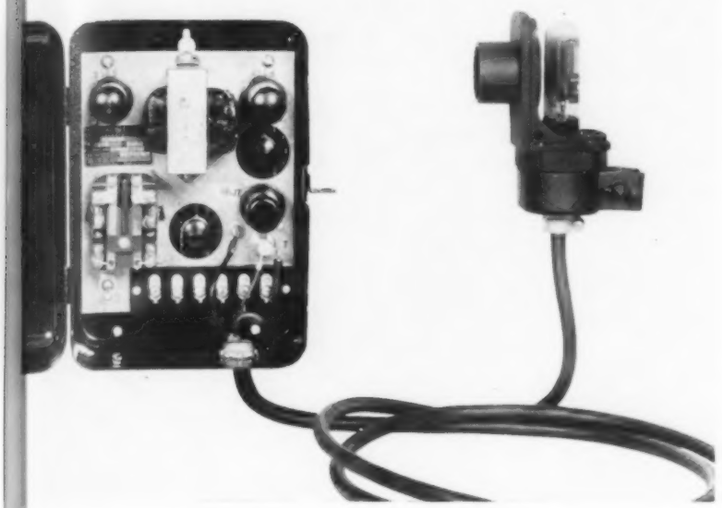


FIGURE 2—This high speed photo-electric relay will operate on a pulse or interruption of light 1/1000 second in duration.

produce or capable of producing a product of such accuracy.

Since a complete description of even a single application of electronic devices, including detailed wiring diagrams, etc., becomes too involved for profitable discussion, the authors prefer to concentrate on the broad principles involved. This paper will, therefore, be confined to a discussion of a number of electronic applications which have already proved successful in various steel mills and of applications which have been made in other industries and which may find a place in the steel industry. The authors are not attempting to point out specific places where these latter applications may be made, but are offering them for your consideration and with the thought they may in the future become useful tools for solving some of your problems.

ELECTRON TUBES

At this point it might be well to review some of the basic principles of electron tubes and tube circuits, and to refresh our memories along these lines so that the applications under discussion will be more readily understood.

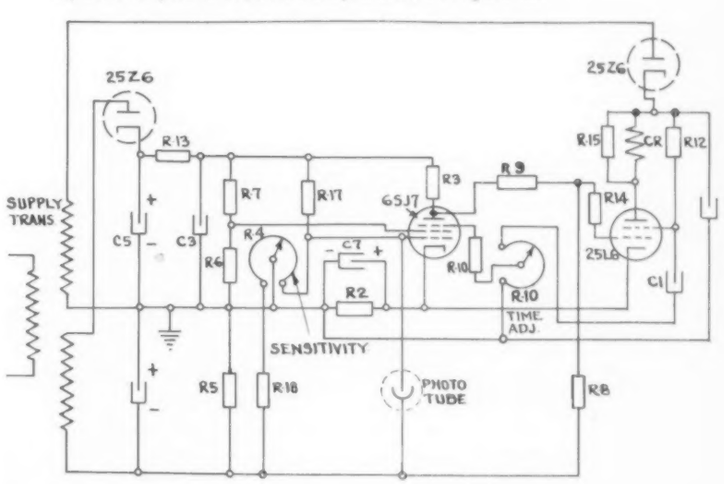
An electron tube can be defined as a gas-tight envelope which contains two or more elements and may be either completely evacuated or contain an inert gas at a suitable pressure. The two essential elements are first, a source of electrons (the cathode) and second, the receiver of the electrons (the anode). In addition to these two main elements, there may be control elements for the purpose of regulating the electron flow.

The most common form of electron tube is the completely evacuated type or vacuum tube. This is the type found in conventional radio receiving sets and in all general amplifying applications. These tubes have, in addition to the two main elements, various combinations of control elements or grids depending upon the characteristics desired. Such tubes are fundamentally low power output devices, but at the same time the control power required is so small that the power amplification is large. One fundamental characteristic of a vacuum tube is that over specified limits the electron flow or output current is a function of the voltage applied to the control grids. A negative voltage between the grid and cathode will restrict the current flow through the tube, while positive voltage will allow full current to pass.

If the power output requirements for a given application are large, gas filled tubes are used. These tubes, except for the physical size, are mechanically similar to the vacuum tubes. The difference is that after being exhausted, an inert gas such as mercury vapor or argon is injected into the envelope. This gas assists the current flow through the tube and as a result larger output currents are available. Though the control power is still comparatively small, it is many times that required for a vacuum tube and as a result the power amplification is less than that of a vacuum tube but still very large when compared with the field power of a generator or the operating power of a magnetic contactor. The control characteristic of a gas-filled tube or thyratron differs from vacuum tubes or pliotrons in that the grid or control element can only prevent the current from starting in the tube but when once started has no further control. Thus, this type of tube is best applied as a rectifier working from an alternating current supply so that the grid or control element can regain control each time the alternating voltage goes to zero.

There is one other tube which differs from either of the above two types in that it has no control element, but the source of electrons is responsive to light. That

FIGURE 3—Diagram of connections of the high-speed d-c. operated photo-electric relay shown in Figure 2.



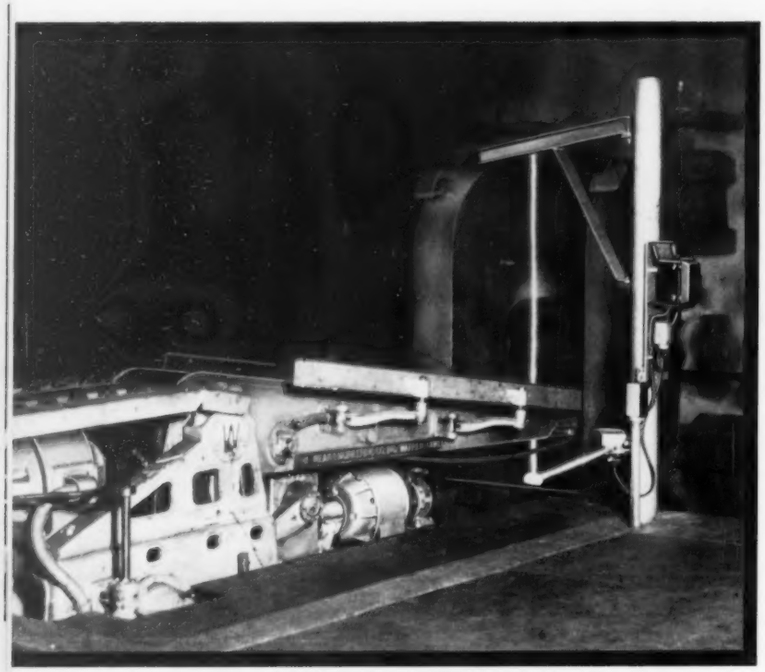


FIGURE 4—General view of automatic sheet catcher installation using photo-electric relays as limit switches.

is, electrons will not be emitted from the cathode in the dark, but a variable amount of current will flow depending on the amount of light falling on the cathode surface. This is called a phototube. The current that flows as a result of the light is extremely small and is usually expressed in microamperes or millionths of an ampere.

Due to the extremely small current that will flow through a phototube, we must use a pliotron as an amplifier in order to operate a relay in response to light on the phototube. Such an amplifier circuit is shown in Figure 1. The secondary windings of the supply transformer are connected so that the grid of the amplifier tube is negative when the anode of the amplifier tube is positive, thus, no current will flow through the tube and the relay in the anode circuit will be de-energized. This condition applies when there is no light on the phototube since the phototube acts as an open circuit. The magnitude of the voltage between the grid and the cathode is determined by sensitivity adjustment P. When light shines on the phototube, causing it to pass current, it will be noted that the grid is made positive with respect to the cathode at the same time the anode is positive, which is a condition for current conduction in the amplifying tube. The relay in the anode circuit will be energized and its contacts will close. The position of the slider on sensitivity adjustment P will determine the amount of light required to cause the amplifier tube to conduct enough current to pick up the relay.

It must be pointed out that this is an a-c. device and because the amplifier will only operate when the anode is positive, light must stay on the phototube for approximately $\frac{1}{6}$ second in order to insure operation of the relay. When high speed operation is desired, it is necessary to add a rectifier in order to put d-c. on the amplifier and on the phototube in order to avoid the blind spots that will occur when operating on a-c.

APPLICATIONS IN THE STEEL INDUSTRY

In discussing electronic applications which have already been successfully made in the steel industry, it is logical to subdivide these into groups corresponding to the type of electronic control used and further into groups with respect to their applications.

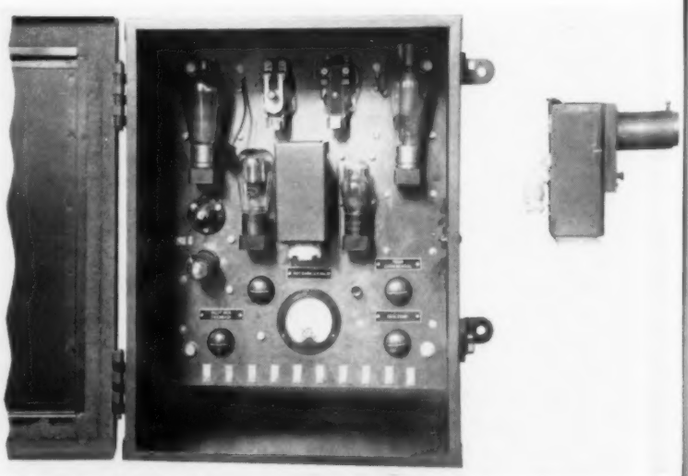
In the first classification, we have photoelectric tubes, gas filled tubes, and high-vacuum tubes as previously mentioned. The following discussion will deal with these three classifications and the various applications which have been made with each of them.

LIMIT SWITCHES

Perhaps the most common usage of the photoelectric relay has been as a limit switch, controlling various electrical functions in response to the presence of some object, either too light, too fragile, too heavy, too hot or too highly polished to permit satisfactory operation with mechanical limit switches. Furthermore, since the light beam will not wear out, photoelectric relays have replaced mechanical switches where the operating conditions are particularly severe.

We have previously described the a-c. photoelectric relay which is responsive to impulses of approximately $\frac{1}{6}$ of a second, but since many applications require operation on impulses of considerably shorter duration, it is necessary to use the d-c. relay. In addition, since the equipment which must operate as a result of these impulses is quite often of a relatively sluggish nature, it is necessary to have some sort of a "memory device"

FIGURE 5—View showing amplifier panel and photo-tube holder for use with a recording or indicating instrument for temperature measurement.



which will hold the relay in the tripped position and will allow it to reset after a predetermined time delay.

There has been available for some time a photoelectric relay, consisting of a phototube, amplifier and thyratron, all working on d-c., that will trip on a pulse of light only 1/10,000 second in duration. There is required, in addition, a time delay relay to reset the photoelectric relay after a definite time.

A new high speed photoelectric relay combined with a vacuum tube timer is now available and should have a wide use as a high speed limit switch. This new relay will operate on a pulse of light or an interruption of light 1/1000 second in duration and will remain operated for a controllable time in order to perform any desired function. The range of this time delay before reset is from 0 to ½ second.

Figure 2 is a photograph and Figure 3 is a schematic circuit diagram of such a relay. The d-c. supply is obtained by rectifying the output of the supply transformer with the 25Z6 rectifying tube. The d-c. output is filtered by means of capacitors Ca, C3, C4 and C5. The 6SJ7 is the phototube amplifier while the 25L6 is the power output tube and energizes the relay (CR). The phototube is shown connected so as to cause relay (CR) to be energized when light falls on the phototube. With no light on the phototube the control grid (7) of the 6SJ7 is held positive through R1 to point 23. With the 6SJ7 conducting current the grid of the 25L6 is brought very close to its cathode potential through R9 and the negative bias through R8 holds the 25L6 non-

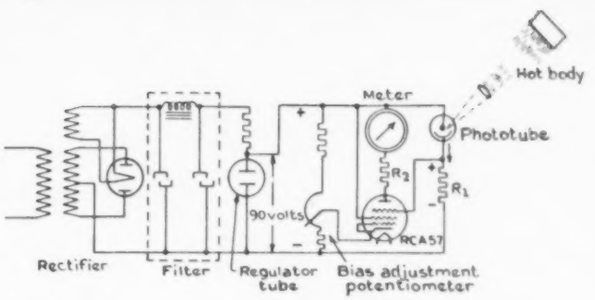


FIGURE 6—Schematic diagram of the amplifier circuit of a photo-electric pyrometer.

conducting. The shield grid of the 25L6 (16) is connected to the positive potential through R2 but no current flows with the control grid negative and capacitor (C1) is charged to the full d-c. potential. No current is flowing through R10 which puts the shield grid (21) of the 6SJ7 slightly negative with respect to its cathode by virtue of the drop through R2.

When light falls on the phototube, grid (7) of the 6SJ7 is pulled negative which stops the plate current through (R3) reducing its drop to zero and pulling control grid (17) of the 25L6 positive. Anode current through CR actuates the relay to perform the desired function. At the same time shield grid (16) acts as an anode and draws current through (R12) which pulls point (16) down to cathode potential. The energy that is in capacitor (C1) starts to discharge through R10 and the current through (R10) is such as to hold the shield grid (21) of the 6SJ7 negative and prevents it from conducting until capacitor (C1) is discharged even though the light is cut off the photo tube immediately. This accounts for the time delay reset that is controlled by the slider on (R10). With the slider down on point (8) there would be no negative voltage on grid (21), and there would be no time delay. The constants of this circuit are so arranged that the vacuum tubes turn on and off with a snap action similar to a thyratron, but they have the advantage of being able to reset on d-c. which thyratrons do not have.

Photoelectric relays have been successfully used as limit switches on automatic sheet catchers (Figure 4), rod mill shears, runout table kick-offs and other similar mill applications and at the present time such a relay is being applied to control the diverter on a skelp mill.

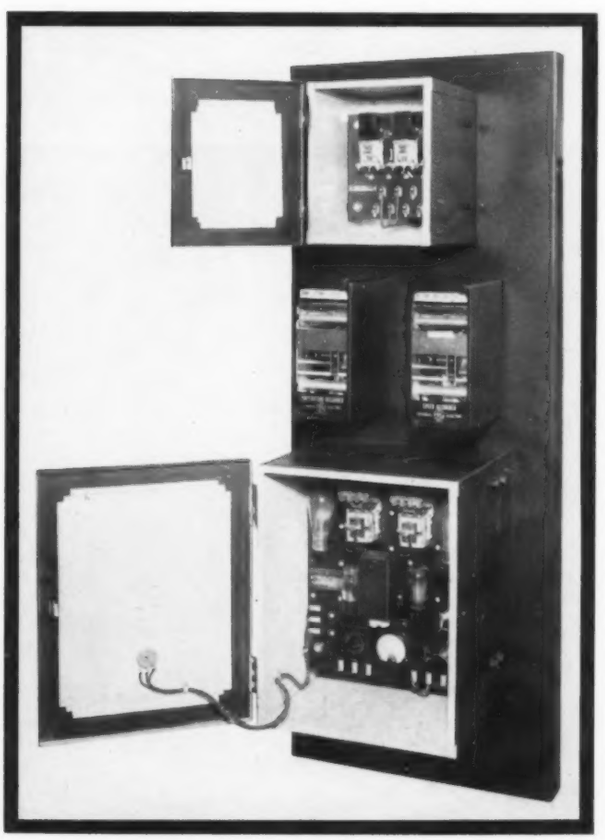


FIGURE 7—Photo-electric temperature control with recording tachometer and temperature indicators, for control of cement kiln operation.

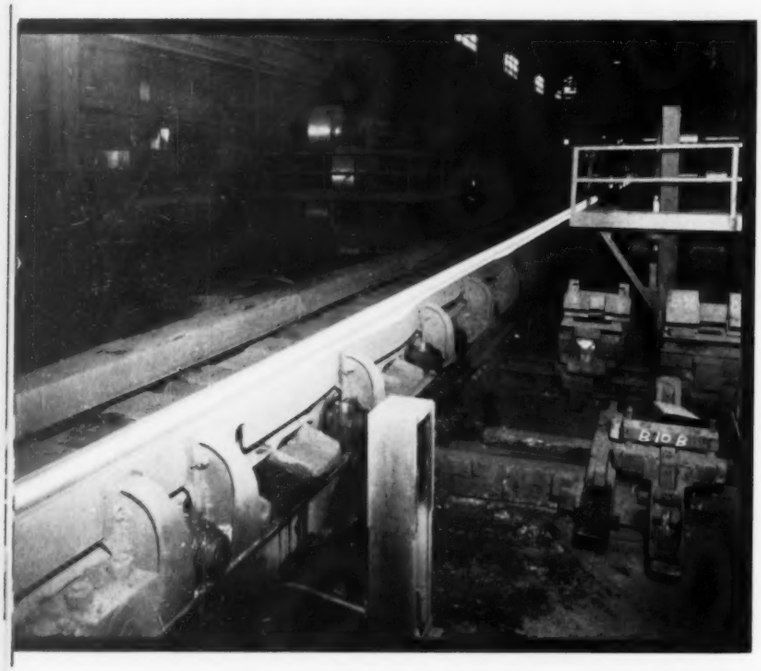


FIGURE 8—The photo-electric pyrometer is best suited to applications using a continuous temperature indication at a permanent location.

In all such cases, successful results depend upon the care exercised in selection and installation of the equipment.

Special housings are provided for relays which must operate under particularly adverse conditions such as the presence of water or excessive dust. Where a great deal of extraneous light, such as sunlight, is present, special masks are used so that the light must enter the relay perpendicular to the lens. When the light beam must pass through a dusty atmosphere or through material which absorbs some light (such as glass or water), the normal distance between the light source and the relay must be decreased to insure sufficient illumination on the phototube.

If such precautions are observed, photoelectric relays can be made to pay dividends in maintenance costs and in operating dependability on the most severe mill applications.

PHOTOELECTRIC PYROMETER

Another very interesting and highly successful application of the phototube is the photoelectric pyrometer. The photoelectric pyrometer is a radiant-energy-responsive device which can be used for indicating, recording, or controlling the temperature of incandescent bodies. The radiant energy from a hot body is directed to the phototube and causes it to pass a current which bears a definite relationship to the temperature of the hot body. This current is amplified by a vacuum tube amplifier and the resulting current utilized as desired.

A novel feature of this pyrometer is that it provides, without appreciable time lag, a continuous indication or record of the temperature of incandescent bodies. This feature makes the equipment distinctive when compared to most other types of temperature measuring devices.

Photoelectric pyrometers have proved their worth in both the steel and rock products industries. The range of temperature covered is 1400 to 3000 degrees F. and it is only necessary to look at the material to be measured, nothing has to come in contact with the actual heat. The advantages of such a system for indicating or recording temperatures of billets on a conveyor or an ever changing mass of material such as a cement clinker are obvious.

Figure 5 shows the amplifier panel and extended phototube holder for use with a recording or indicating instrument. This is the apparatus necessary to record the continuous temperature of any material within the range of 1400 to 3000 degrees F. Figure 6 shows a control amplifier with the associated contactor panel for controlling a cement kiln speed. The second recording instrument is a tachometer recorder to give a simultaneous record of the speed, but there is available a single instrument with both temperature and speed on a single paper chart.

The distance of the phototube from the material being measured is not critical. It is only necessary to have the image of the hot body completely cover the aperture in front of the phototube. For a given lens focal length and distance from the hot body, there is a

FIGURE 9—The temperature indicating instrument may be placed in the roller's pulpit, as in this 48 in. shape mill.

minimum size of body that can be measured. Therefore, in order to correctly apply such a pyrometer it is necessary to know the minimum area that is to be scanned and the distance the phototube holder must be mounted from the specimen.

A schematic diagram of the amplifier circuit is shown in Figure 7. High amplification of the minute phototube current is obtained by using a multi-grid amplifier tube. The phototube circuit and amplifier circuit are supplied with direct current from a small rectifier and filter included in the equipment.

The amplifier-tube grid voltage is determined by the phototube current flowing through R_1 and by the position of the bias adjustment potentiometer. The anode current passes through a resistor R_2, in series with which the indicating or recording instrument is connected.

Since voltage variations would affect the accuracy of the equipment to a serious degree, it is necessary to incorporate means for maintaining the voltage constant. For this purpose a voltage-regulator tube is employed. To further insure amplifier stability, a ballast tube is connected in series with the amplifier cathode heater. The resistors employed in the system and particularly the phototube resistor R_1, are of low-temperature-coefficient material and are so mounted as to minimize the possibility of leakage current.

The photoelectric pyrometer is best suited to those applications in which it can be permanently installed at a location where a continuous indication or record of temperature is desired. Numerous installations have been made, in the last several years, on structural mills, pipe mills, etc., and just recently a new application has been made by the Jones and Laughlin Steel Corporation in their revolutionary Bessemer flame control process. Figures 8 and 9 show a pyrometer installation in a shape mill.

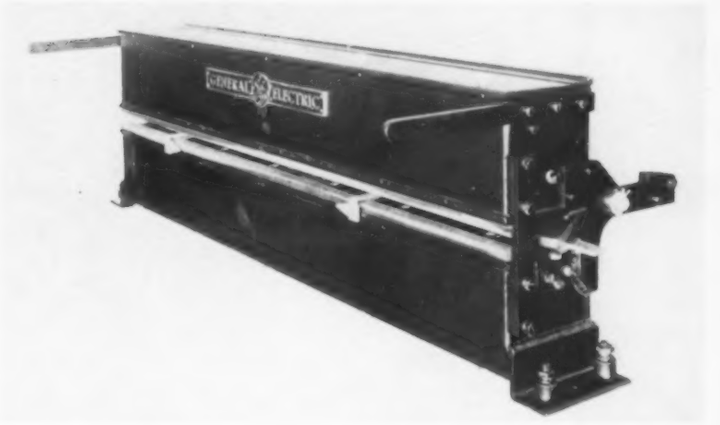


FIGURE 10—The scanning head of the pin-hole detector houses the light source above the strip passage line, and photo-tubes below.

FIGURE 11—A simple and sturdy marking device has been developed for marking the strip where the defects appear. The resulting mark on the strip is several inches long and is readily seen by the inspectors either before or after the tinning operation.

PIN-HOLE DETECTOR

Photoelectric inspection is a large and useful field which has not even been scratched at the present time. The steel industry was one of the first to utilize this type of photoelectric control in the form of pin-hole detectors for detecting small holes in tinplate stock. Other applications have been made in counting sheets on shearing lines and in conjunction with micrometer gauges for measuring strip thickness on cold mills.

The pin-hole detector is the most recent and probably the most interesting application which has yet been made in this field. In fact its acceptance in the steel mill has caused numerous other industries to experiment with similar devices.

It is, of course, unfortunate that in rolling tinplate minute holes appear. However, since the causes of the holes appear to be so numerous in the present rolling processes, the pinhole detector affords an excellent means of eliminating defective sheets before shipment to the ultimate customer. It also provides a way to determine the effect of corrective changes which may be made in the methods of rolling the steel.

The complete unit for detecting and indicating the detection of holes as small as .015 in. at speeds up to 100 ft. per min. consists of a scanning head which straddles the moving strip and a relay panel which is mounted wherever convenient. The scanning head houses the light source in a steel case mounted above the strip and the phototubes in a similar case below the strip. Such an equipment is shown in Figure 10.

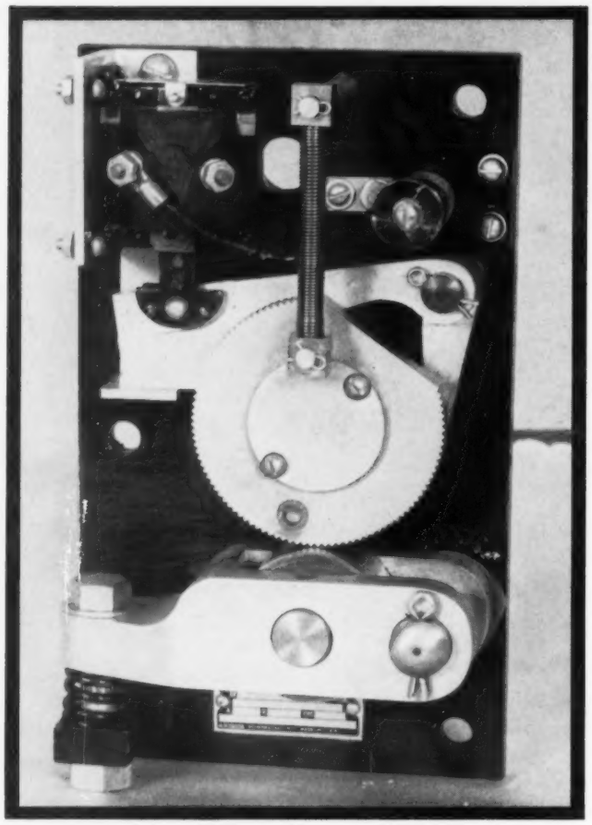


FIGURE 12—View of tinplate marker with cover removed, showing holding solenoid, stop lever, marking gear, pressure spring, roller, and adjustment bolt.

As long as there are no holes in the strip, no light reaches the phototubes and the equipment is inactive. As soon as a small hole passes through the scanning head, the light strikes one or more of the photo tubes and sets up an impulse which is amplified and transmitted to the relay panel where it trips a thyratron tube and operates a relay. This relay can be used to stop the strip or to actuate any other desired control. Most of the installations up to the present have been made on trimming and shearing lines where diverter gates are already installed for discarding off gauge sheets. The pin-hole detector can be used to operate this gate and discard those sheets which are defective because of holes.

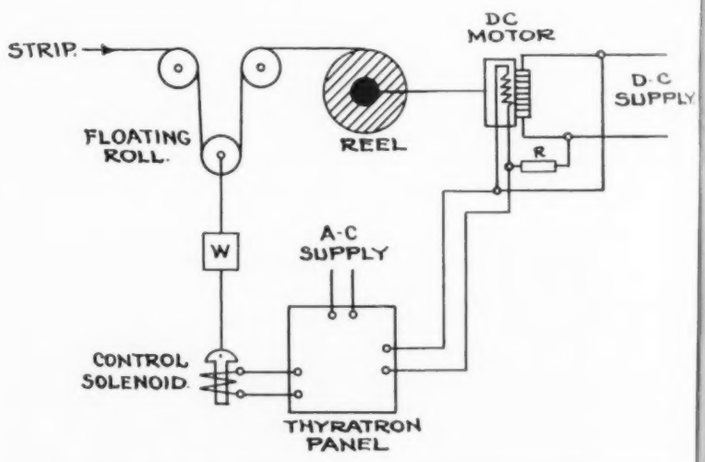
In addition, a very simple and sturdy marking device, shown in Figures 11 and 12, has been developed for marking the strip where the holes appear. Since paint and ink are likely to come off when the strip passes through the leveling rolls and since they will most certainly be removed by the pickling bath which precedes the tinning operation, such substances do not appear to be satisfactory for the purpose and therefore a mark consisting of a series of indentations in the surface of the strip has been used. Such a mark is made by means of a knurled roller which is brought into contact with the strip by a small solenoid. The resulting mark is several inches long and is readily seen by the inspectors either before or after the tinning operation.

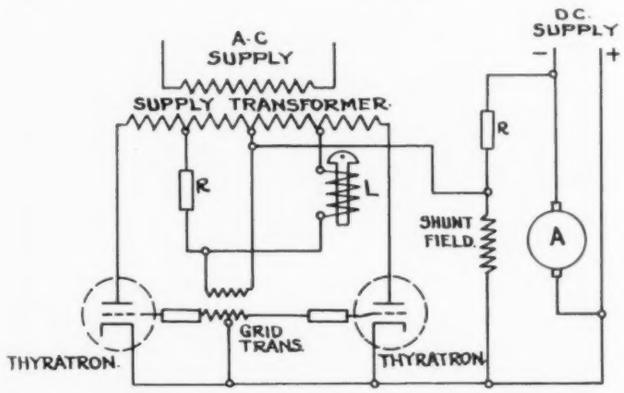
The acceptance of the pin-hole detector by the steel industry and the fact that it has passed with flying colors is further indication that electron tubes can be satisfactorily applied in the steel mill if sufficient thought is given to the conditions which must be met.

Since there are very few moving parts and since the tubes are used very conservatively, the actual maintenance has proved to be low.

In spite of the fact that phototubes and vacuum tubes appear to be fragile, if the proper mounting is provided by the manufacturer of the equipment, there is no need for the customer to provide a shock proof platform for mounting the scanning head. Due to local conditions in one installation, it was necessary to mount the scanning head directly on the shear and despite the sudden jar each time a cut was made, the equipment was adjusted to reduce false operations to a satisfactory

FIGURE 13—Photo-electric tube control has been applied to the control of small d-c. motors driving winding reels, as shown in these diagrams.





minimum and no lessening of tube life was apparent. We do not recommend this procedure but it illustrates what can be done with the proper design.

MOTOR CONTROL

Because thyratrons are inherently rectifiers, they make an excellent medium permitting the use of small d-c. motors in an a-c. equipped plant. Besides being rectifiers they have control features that make possible excellent results, for instance in the form of speed or tension control.

Many schemes have been evolved for maintaining an essentially constant tension when coiling steel strip or wire on a reel. These vary from the elaborate constant current regulator variety down through three-field generators to the simple rider roll rheostat.

Thyratron control has also been successfully utilized for controlling small d-c. motors driving winding reels. The simplest and most obvious application is tension control by means of a floating roll as shown in Figure 13. The material to be handled is passed over three pulleys or drums, two of which are fixed and the third one supported by the loop of material. As long as the sides of the loop are vertical, the tension during steady state conditions is one-half the weight hanging from the floating roll or pulley. This is true regardless of the position of the loop or the speed of the motor. During changes in speed, the inertia of weight W will upset the ideal condition of absolutely constant tension, but during normal operation the rate of change will be very slow and the effect of the inertia of weight W can ordinarily be neglected.

If the material to be handled is such that it can not be flexed to the extent shown in the illustration, it is possible to mount the floating roll between two widely separated stands with a shallow loop. The tension then varies with the position of the loop, varying from a minimum at full loop to a maximum at small loop. However, this is acceptable in some cases where the tension is not critical and can vary between certain limits.

In either case, the electrical equipment for controlling the reel motor is the same. Connected to the floating roll is the core of a standard a-c. solenoid which is the control element for the thyratron panel. The connections through the panel and to the reel motor are such that the motor will be slowed down as the loop becomes smaller and speeded up as the loop becomes larger. With the connections made in this manner it is obvious that the length of loop will be maintained somewhere between the limits of the solenoid travel.

The two thyratrons are connected in what is commonly termed a full-wave rectifier circuit. By this we mean that each tube conducts a half-wave of current

FIGURE 14—View showing the application of photo-electric control to a wire-drawing winder.

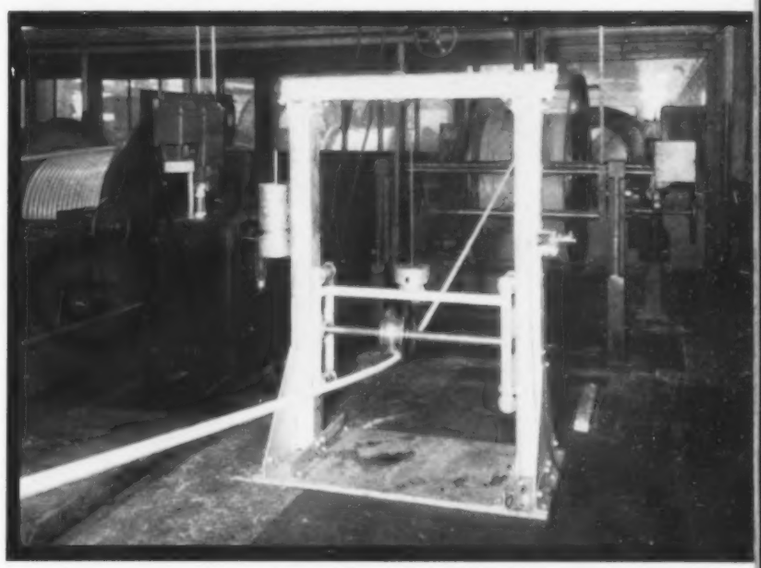


FIGURE 15—This floating roll is used in connection with photo-electric control on the constant tension reel drive of cable machine.

and the connections are such that these half-waves are directed through the load in the same direction to become the equivalent of d-c. As stated previously, the grids in the thyratrons cannot control the flow of current through the tubes when the current has once started, but they can prevent or delay the starting. It is the delayed starting feature that is used in this control. An a-c. voltage is applied to the grids from a grid transformer, the primary of which is connected in a phase-

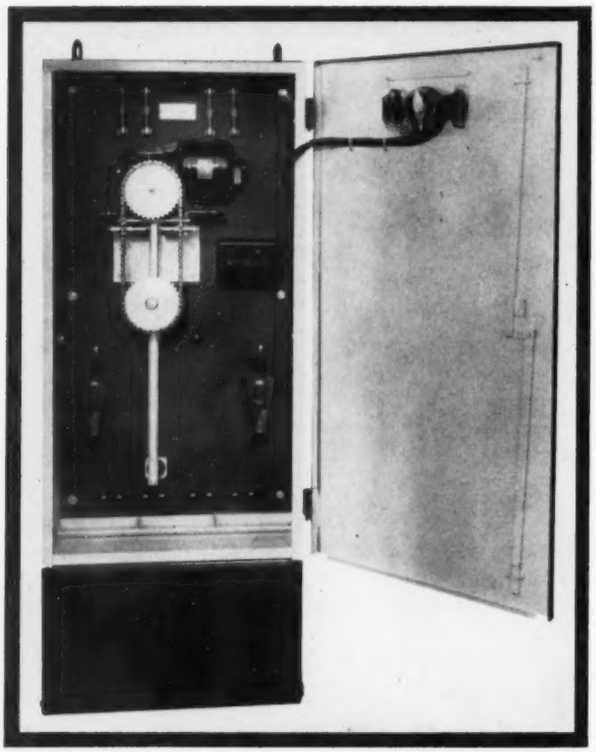


FIGURE 16—Motor-driven timers on seam welder photo-electric control offer a definite timing.

shifting circuit. This phase-shift circuit consists of a resistor R and the coil of the solenoid connected in series across a mid-tapped a-c. supply. With the primary of the grid transformer connected between the mid-tap of the a-c. supply and the junction of the inductance and resistance, the voltage on this transformer will be varied in phase with respect to the supply as the inductance is varied. Therefore, as the floating roll moves up and down pulling the core in and out of the solenoid coil, the grid voltage will be varied in phase with respect to the supply.

With the core of the solenoid in the extreme out position, that is minimum inductance, the grid voltage will be nearly in phase with the supply or anode voltage. This means that the thyratrons will conduct full half-cycles as the grid will be positive at the same time the anode is positive. As the core is moved into the solenoid the grid voltage will lag the anode voltage, in other words it will become positive some time after the anode voltage has become positive, which means the thyratron will be delayed in firing and will only conduct a portion of a half-cycle. If this is carried to the extreme, that is to infinite inductance, the grid voltage will be 180 degrees out of phase with the anode voltage and the grids will never be positive at the same time the anodes are positive and therefore the tubes will not conduct even a part of a half-cycle. From the above explanation it should be apparent that we can control either a motor armature or a motor field over a wide range without sliding contacts or appreciable mechanical power.

This same floating roll system is also used on straight rheostatic control such as the loop rheostat in a continuous pickling tank. Where there is sufficient power to operate a rheostat and the results are all there is to be desired, there is no necessity of tube control. But, if the wire or strip is thin or small and the tension light, or the speed is so high that the system is subject to hunting, thyratron motor control should be considered. Figures 14 and 15 show a thyratron controlled reel on wire drawing and cable winding machines.

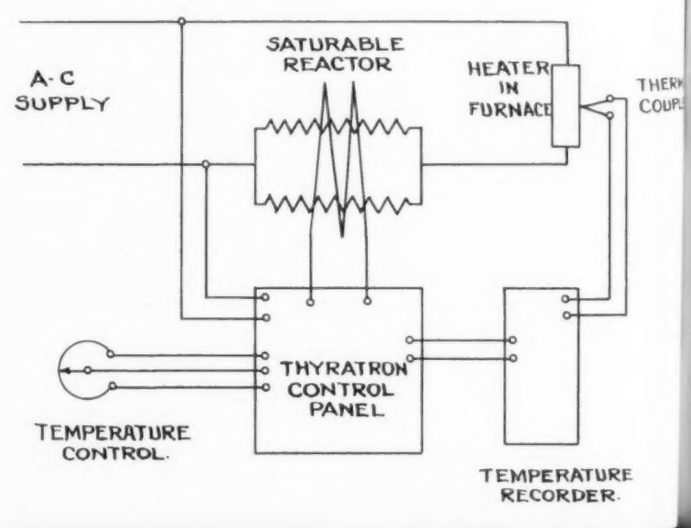
One recent installation, utilizing the above scheme, was made on a strip annealing furnace. Here, seven strips of silicon steel are wound on individual reels after they travel through the electric, catenary type furnace. In this particular instance pressure blocks provide tension for the individual strips and the individual thyratron control of each motor acts mainly as a speed regulator to maintain a loop.

For very high speed applications, such as reeling on a wire drawing machine at 3000 ft. per min., modification of the above system of control is sometimes desirable to avoid hunting. A selsyn is geared to the floating roll so that the output voltage varies with the position of the loop. The selsyn output is applied to a grid circuit in such a manner that electrical damping can be employed to eliminate hunting.

Speed regulation by thyratron control has been developed for those applications that require accurate control of the speed. By means of electronic circuits and pilot generators it is possible to hold the speed of a motor very nearly constant over wide ranges of load. For economic reasons armature control is limited to motors of 10 or 15 hp.; however, by means of field control it is possible to control larger motors economically with the present tubes.

Thyratron motor control has been successfully applied to the electrode motor on automatic arc welding heads.

FIGURE 17—Schematic diagram of furnace temperature control system using the saturable reactor.



In this application the direction of rotation as well as the speed of the motor is controlled as a function of the arc voltage. High arc voltage drives the electrode wire toward the work and low arc voltage reverses the voltage applied to the motor armature and drives the motor in the opposite direction. Under the steady state condition the motor feeds the electrode just fast enough to maintain a constant arc voltage. The voltage to be held and the speed of response is under control by two knobs on the control station.

Another adaptation of this system of regulation is the control of the electrode motor in an arc furnace. In this case a constant current is maintained rather than a constant voltage.

RESISTANCE WELDER CONTROL

Electronic control has revolutionized the use of resistance welding because of the precise timing and synchronous starting which permits the welding of materials and alloys previously considered impossible to weld in production. The lack of moving parts in this control means that the maintenance is reduced to a small part of that required for magnetic control. This means that on severe duty or high speed jobs, electronic control offers a real advantage even though its precision is not required for satisfactory welding.

The feature of synchronous control, or in other words, the switching of this lower power factor load with minimum transients, is a major item. First, the lack of transients lowers the demand on the supply lines and causes less interference between welders and other connected load on the same feeder. The saturation of the welding transformer is also eliminated which means less heating of the transformer. This is particularly important on seam welders where the secondary loop is closed continuously and the transients if present would be cumulative. The welding results are also affected because even though the timing is constant the heat will not be the same for each spot unless the power is applied synchronously.

The timing circuits used are designed for precisely accurate control and are calibrated in terms of cycles of the applied power. The control is arranged so that full cycles only are used, that is, if one-half cycle is passed by one power tube the other is made to follow. This feature avoids any chance of a d-c. component saturating the transformer.

Electronic timing circuits have the advantage of easy adjustment and can be calibrated at the factory. This is the form most widely used for spot welding. Seam welders, however, require a continuously repeating cycle of on and off intervals that can be generated by a synchronous motor driven mechanism. This mechanical control dictates which cycles are on, the actual time of firing is determined by an electronic circuit. In this way the accuracy of firing is not affected by minor back-lash or hunting of the driving mechanism. This mechanical type of seam welder control, although not as easily adjusted for different welding cycles as the complete electronic control, offers a definiteness of timing that is apparent at a glance and appeals to the unskilled operator. Figure 16 is a photograph of such a motor driven timer.

The use of electronic controls makes possible another feature that is coming into greater demand, this is heat control by the phase shifting method. A control equipped with this feature has a small dial to control the current to the weld. The range of control on 440 volt circuits is from 100 per cent current to 20 per cent current. This system can be used for complete control of the heat or it can be used as a vernier vor the conventional primary tap method. This control of the magnitude of the r.m.s. current in the weld is accomplished by delaying the starting of the power tubes, which means for currents less than 100 per cent the wave is discontinuous. The effect of this chopped wave on the welding has been carefully checked and found to give identical results when compared to full waves of lower magnitude.

The primary line current will be higher when the secondary current is reduced by phase control than it would be if reduced to the same value by changing primary taps. This is because the turn ratio of the transformer is changed when the taps are changed, but with phase control the transformer turn ratio stays the same. The power is, of course, the same in either case so there is no loss in efficiency.

Because resistance welding machines are as a general rule of low power factor, high line currents are required to produce a comparatively small amount of heat in a weld. A method of power factor correction has recently been developed that will permit initiation of the spot without transients and the welder will operate at unity power factor. The system of control not only avoids transients but also reduces the line current to a value corresponding to the actual power consumed in the weld and surrounding metal. The advantages are less transients and better relations with the power company.

Where the advantages of synchronous starting are unnecessary, but where it is desirable to eliminate the maintenance associated with moving parts and arcing contacts, the ignitron contactor is available. This is a compact electronic switch of high current capacity, without moving parts. It is used in place of a magnetic contactor to close and open the primary circuit of a resistance welding machine and can be substituted on existing installations to give millions of noiseless operations, without servicing and to do so at very high speeds.

The ignitron contactor includes two water-cooled ignitron tubes arranged to perform essentially the same as a single pole magnetic contactor. It is available in standard ratings up to 1700 amperes on duty cycles involving current flow for 50 per cent of each minute or 5300 amperes for 10 per cent of each minute.

SATURABLE REACTOR TEMPERATURE CONTROL

The voltage regulating circuit, which has been used for some years in theater lighting control, has recently been applied quite successfully to the temperature control of electric furnaces. With this circuit, a reference voltage, which represents the desired temperature, is automatically compared to a voltage, which represents the actual temperature, and the saturation of a saturable reactor is changed to make the output voltage agree with the reference.

Figure 17 is a schematic diagram of such a furnace temperature control system. The voltage on the heaters is controlled by the saturable reactor shown in series with the a-c. supply. A saturable reactor without any d-c. current in the saturating winding has the characteristic of offering a high impedance to the current flow. This reduces the voltage on the heaters below the range over which the furnace is to be regulated. This impedance is reduced as d-c. is applied to the saturating winding. When full saturating current is applied, there will be full voltage on the heaters. A special recording instrument is used that has a potentiometer mounted inside and the slider geared to the recording arm. In this way a feed back voltage is delivered to the thyratron panel that is proportional to the temperature in the furnace.

As stated before, the control compares the value of this feed back voltage to the voltage from the reference potentiometer and delivers sufficient d-c. power to the saturable reactors to keep these two voltages equal. Thus the temperature will follow the setting of the reference potentiometer.

This system of furnace control has been successfully applied to chemical processing and to strip annealing furnaces. Figure 18 shows the control panel for such an installation.

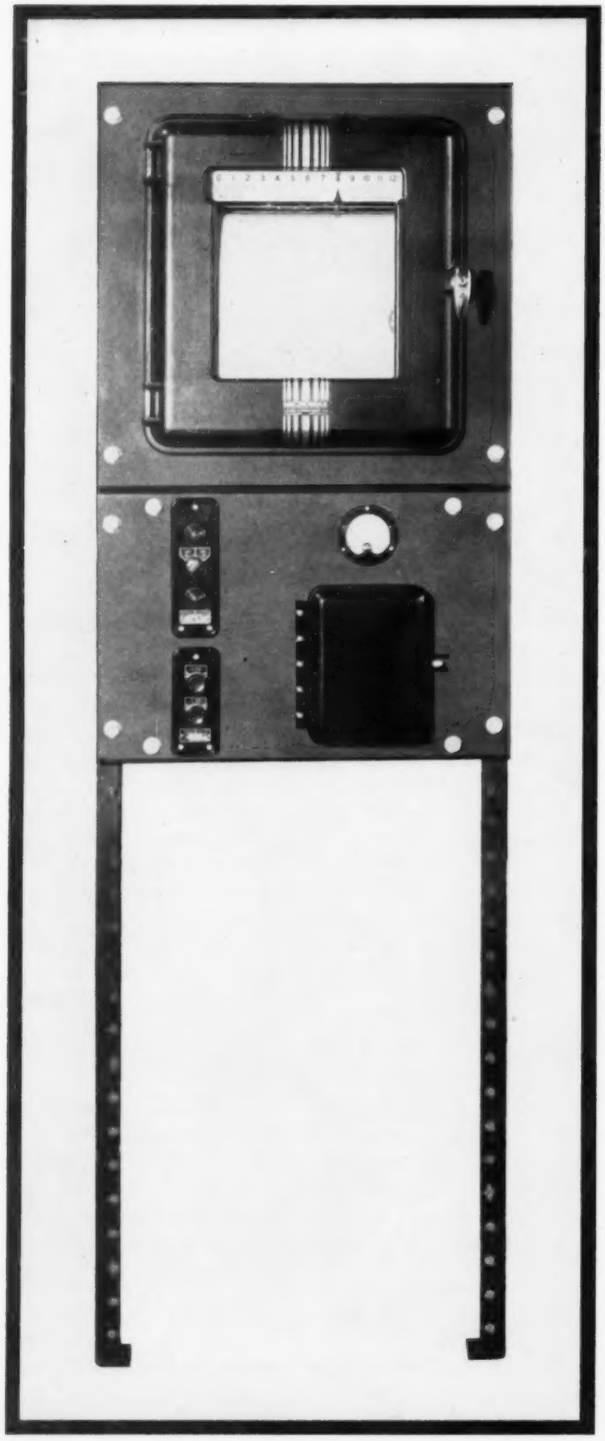


FIGURE 18—View of complete furnace temperature control panel using the saturable reactor method. (above)

BATTERY CHARGERS

While this paper deals primarily with electronic control equipment and despite the fact that previously a paper on power tubes was delivered before this same group, the authors wish to mention a new development in the line of power applications.

FIGURE 19—Gas-filled photo-tubes are used in this constant potential battery charger. (right)

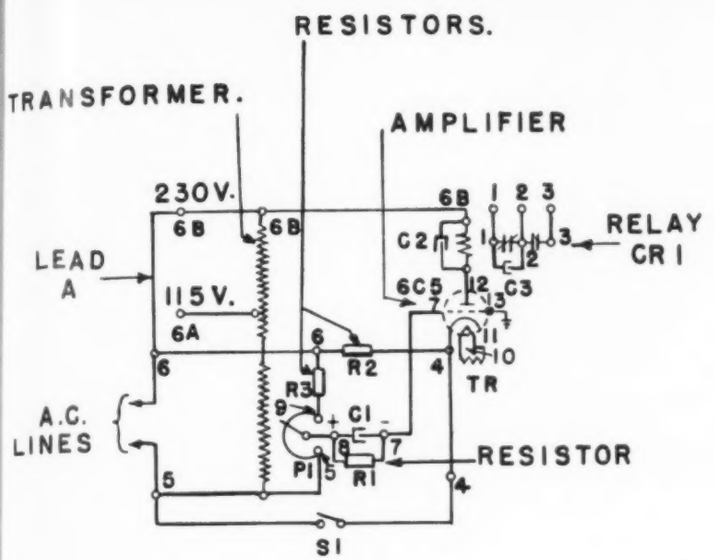


FIGURE 20—Simple diagram of vacuum tube application in a time-delay relay.

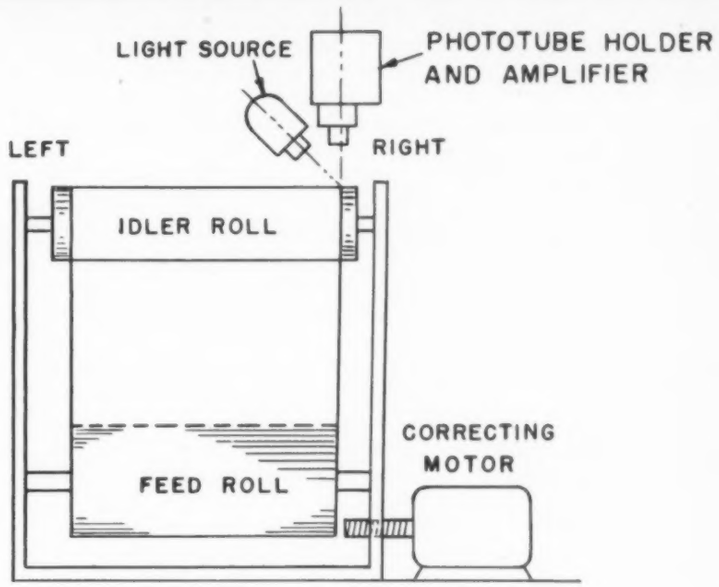


FIGURE 21—Diagram showing scanning and correction method used in side register control on paper handling machine.

This is the constant-potential phanatron battery charger. Phanatrons are gas-filled tubes which differ from the thyratrons in that they do not have a control element, or grid. While developed primarily for power plant and substation service to be used as a trickle-charger for floating station batteries, it is by no means limited to this field.

These chargers, shown in Figure 19, are designed for 4.5, 12.5, and 25 ampere outputs. These can be designed for battery voltages from 50 to 500 volts. In the smaller sizes they are entirely self-contained and are completely automatic and self-regulating. In the 25 ampere size, they are designed to operate from a three-phase power source and are either self-contained in a case for floor mounting, or in a wall mounted case with separately mounted anode transformers and reactors.

Controls are provided for adjusting the voltage and current of the charger. The voltage characteristic is exceptionally flat from no load to full load, and then breaks abruptly into a relatively constant current characteristic. The d-c. voltage regulation is within 1 per cent for a 5 per cent variation in the a-c. supply.

Since these phanatron chargers are simple in design, have few movable parts, require little space, and cannot be overloaded, they have met with widespread approval.

TIMERS

Various types of timing devices, both mechanical and magnetic, have been used in the steel industry over a long period of time. The d-c. definite time magnetic relay of the flux decay type, the mechanical timer of the escapement type, and the a-c. time relay driven by a synchronous motor are familiar to most of us.

In addition to these common types, in order to meet a demand for a long lived, reasonably accurate time delay relay with a very wide range of time adjustment, a line of vacuum tube timers has been developed. With this type of timing element there are no mechanical parts, such as gears or clutches, which are likely to wear out or need adjustment.

The elementary diagram of such a timer is shown in Figure 20. In order to keep the size of the capacitor and resistor to a minimum, we utilize a vacuum tube amplifier for the purpose of detecting the change in voltage in this low power circuit and arrange it to operate a relay connected in the anode circuit. With switch S-1 open as shown, the tube cathode is connected to one side of the a-c. line through resistor R-2. The timing capacitor C-1 is charged by means of the grid current to a value corresponding to the peak of the voltage from one side of the line (6) to the slider of the potentiometer (P1). The capacitor is charged in this manner because the grid of the tube acts as an anode and collects the electrons from the cathode. Closing the switch (S1) connects the cathode to the other side of the a-c. line. The voltage that will now appear between the grid and cathode of the tube consists of two parts, first, the a-c. voltage from the cathode to the slider of potentiometer (P1) and second, the d-c. voltage across capacitor (C1). As the d-c. voltage on the capacitor is greater than the a-c. voltage, a negative potential is applied to the grid and the tube will not pass current. However, the d-c. voltage immediately commences to decrease because capacitor (C1) discharges into resistor (R1). After a definite time this d-c. voltage will be reduced to such

an extent that the vacuum tube will pass sufficient current to pick up the relay in the anode circuit. The length of time for the above operation to take place is determined by the position of the slider on potentiometer (P1). Moving this slider nearer to point 5 will increase the time as it increases the voltage to which capacitor (C1) is charged and lowers the a-c. voltage in series with the grid when switch (S1) closed.

This vacuum tube timer is a small, compact unit designed for operation from 115 or 230 volts at 60 cycles. It is standardized in ratings which give an adjustable time delay of .054 to 1.08 seconds as a minimum and 3 to 60 seconds as a maximum. Any timer is adjustable over a 20 to 1 range and this range can be shifted up or down, within the above limits, by a simple modification of the circuit. Fluctuations in the voltage source will affect the repetitive accuracy somewhat, but since this is only in the neighborhood of 3 to 5 per cent for a 5 per cent change in voltage, it is not enough to cause concern in the majority of cases.

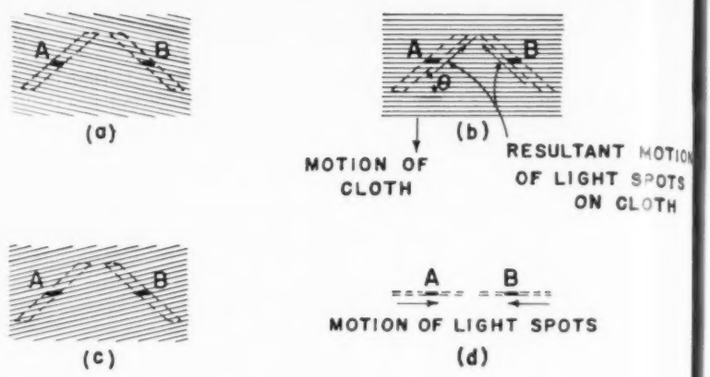


FIGURE 22—In the textile industry, photo-electric inspection equipment detects any skew in the weft threads.

MISCELLANEOUS INDUSTRIAL APPLICATIONS

In addition to those applications already discussed, there are a number of others which, although not yet made in the steel industry, have met with considerable success in other industries. Since processes and method of manufacturing change from time to time, it is quite possible that some of these may become applicable to steel making processes in the future and for that reason the authors have chosen to mention several of these here.

The ability of the phototube to control machines in accordance with printed matter has proved to be one of the greatest contributions that electronic control has made to automatic machines. Packaging machines have been changed from single sheet feed to roll feed with enormous savings in material and labor. Other continuous feed operations such as bag manufacturing have been changed to photoelectric register rather than manual with improved products and less spoilage. Postage stamp perforators have changed from manual to automatic control with the result of higher production and a reduction in spoilage from 15 to 3 per cent.

It is interesting to note that almost without exception users of these register controls report savings of such a magnitude that the purchase price of the equipment is liquidated in less than a year. You will all agree that this is truly a good recommendation.

Register controls are divided into two general classifications, cut-off and side register. The cut-off register controls are used where printed wrapping paper is fed in a roll and each sheet is cut off and the product wrapped with a given relation to the printing. Approximately 75 per cent of the candy and staples on the grocer's shelves is handled this way and a close inspection will reveal these register marks.

Side register control is used on slitters where a number of small wrappers or designs are printed on a wide sheet and then slit into rolls of individual wrappers by following along lines printed with the design. Other times it is necessary to keep the edge of the material going through a machine at a definite relation to a trimmer or other process.

Figure 21 shows a correcting method used on paper handling machines. In this case the material and roller are of contrasting colors and the control is arranged so that with the roller under the scanning head the feed and idler roll are moved to the right. If the material is under the scanning head, the feed and idler rolls will move to the left. Thus a balance is reached that will keep the edge of the material under the middle of the light spot. With equipment such as shown in Figure 21 it is possible to hold the edge of the material to plus or minus $\frac{1}{64}$ in. while traveling at 1500 ft. per min. It is this type of equipment that requires careful coordination between the machine manufacturer and the control manufacturer. It is possible to detect with photoelectric means a deviation of 1/1000 in., but the real problem comes in correcting the material without hunting at a speed necessary to keep up with the deviations that will occur.

Figure 21 shows an application using reflected light. However, with opaque material such as steel, transmitted light would be the best arrangement to use. That is, a light source is put on one side of the material and the phototube is mounted on the other side with the edge of the material cutting the light beam.

If accuracies such as those mentioned above are not required, it is possible to de-sensitize the control by using a larger beam of light. By using less sensitive indication, the problem of correcting without hunting is greatly simplified.

The textile industry has accepted a form of photoelectric inspection equipment called the weft straightener control. In this application, phototubes scan the cloth as it passes through a machine and detect any skew that is present in the weft threads. Figure 22 illustrates the method of scanning. (a) Shows the interrupting conditions for skew in one direction. It will be noted that light beam (A) is cut by 14 threads during the same interval that only 9 threads cut light beam (B). This causes two different frequencies to be generated in the photoelectric amplifier outputs. (b) Shows the condition on no skew and it will be noted that both light beams are cut at the same rate, which results in

identical frequency generation. (c) Shows how with the skew opposite to that in (a) the difference in frequencies will be the reverse of that generated by the conditions of (a).

The output of the photoelectric amplifiers is put into a frequency detecting circuit that causes one set of controls to be energized when the frequency difference is one way and another set of controls to be energized when the frequency conditions are reversed. If the two frequencies coincide, no action will be taken. The two different controls that are energized when the frequencies are not the same apply the necessary correction to the machine to straighten the cloth. In this way the output of the machine is constantly guarded against this defect without the attention of an operator.

In keeping with the general trend for improved living and working conditions, an indoor lighting control has been developed. With this control the light level in a school room, office, or factory is watched continuously by a phototube and when the illumination drops below the preset level artificial lights are energized. If conditions outside change and artificial lights are no longer necessary, they will be turned off.

The result is adequate illumination at all times without the usual waste of electric power and lamp life. Surveys of schoolrooms show that there is a definite improvement in scholastic results after this modern lighting control was installed. If under the old system the person responsible for the operation of the lights insured plenty of light at all times by burning the lights unnecessarily, the automatic control will pay for itself in power and lamp maintenance in a year.

The control for such a purpose is a simple amplifier operating a relay which in turn controls the contactor in the lighting circuit. The phototube and amplifier are built into a unit that can be mounted on the wall of the room to be lighted. The line contactor is in a separate unit that can be mounted in a convenient place to control the lighting power.

Smoke detection with a continuous record of conditions and a limit alarm is a great help to any industrial plant or central station with coal-fired boilers. The advantages are twofold; first, it is considered an indication of efficiency of firing, and second it is an excellent guardian when the plant is located in a district with a smoke ordinance. The problem of detecting smoke is a simple one, as it is only necessary to mount a sensitive photoelectric relay on one side of the stack and a light source on the other. As smoke comes between the light source and the phototube the amplifier output will be affected. There are a few practical problems such as soot collecting on the lenses and cover glasses, but by proper design this can be overcome.

The calibration of such an equipment is somewhat of a problem beacuse of the difficulty in getting a clear stack to set the zero smoke point. There is not only the initial installation calibration, but for maximum dependability the calibration should be checked periodically. However, there are solutions to this problem, and a great many such equipments are in successful operation today.

There are two general forms of equipment available. The simplest has a limit alarm circuit and a recording instrument that will record the time of any high density conditions. The record does not give any indication of the amount of smoke, just that it was either low enough or too high. Another form is available which will provide a continuous record of the actual smoke condition. A limit alarm can be added to this type so that a warning can be sounded if the smoke density exceeds the desired amount.

SUMMARY

Since control equipment which utilizes electron tubes differs considerably from that built with ordinary magnetic devices and since the control circuits appear, at first glance, to be much more complicated, there has been a definite tendency for steel mill engineers to avoid the use of electronic devices where possible. This feeling has also been fostered by the apparent fragility of equipment which utilizes electron tubes.

In spite of this, however, as the foregoing discussion reveals, many successful applications have been made where other equipment was not suitable for some reason or other. In fact, a few hardy souls have used electron devices in preference to contactors, etc., even though the latter appeared to meet their requirements. The success of such electronic equipment already installed has helped and is helping to allay the fears of steel mill engineers so that they no longer hesitate to consider the use of electronic control or feel at a loss in operating and maintaining it.

If the equipment is well designed, is manufactured in accordance with and existing industrial standards, the application engineering is sound, electronic control will pay big dividends.

DISCUSSION

PRESENTED BY

F. D. EGAN, *Electrical Superintendent*, Bethlehem Steel Company, Lackawanna, New York.

E. H. VEDDER, *Manager*, Electronic Control Section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

F. D. EGAN: This subject is more or less foreign to the average steel mill engineer, however, it is my opinion that tube control is destined to play a large part in future steel mill applications.

I think that Mr. Palmer and Mr. Poole have done an excellent job in presenting this paper and I believe that the steel mill engineers will seriously study these applications presented here. We have been associating the electron tube with radio and various minor applications in steel mills, however, very few of us thoroughly understand the function and characteristics of the electron tube control circuit. This paper will be a step in the better understanding of this piece of apparatus by steel

mill men. This paper should be followed by others to educate the engineers in the use of this control and to keep him posted on the new developments along this line.

We have used tube control in some few applications with excellent results and have had some applications that did not work out. The failures may have been caused by the improper selection of equipment or the improper hook-up, in either case it comes back to our lack of knowledge of the characteristics, and limitations of the tubes and their auxiliary equipment.

E. H. VEDDER: I believe Mr. Palmer has given a very good story of the type of thing that can be done in steel mills, particularly in his closing remarks when he said that the electronic equipment has suffered in its application in steel mills largely because of its apparent fragility.

Actually, we don't expect the tubes to be subjected to the crashing and banging of the steel. I don't know why we should worry about the apparent fragility of the tubes themselves, as they are always encased in a good, husky steel box. In fact, a steel box is just as husky for electronic equipment as for any other kind of control equipment used in a steel mill.

I believe there is also a tendency on the part of people using electronic equipment to feel that it is mysterious and tricky. They can't see what goes on in the tubes, so they feel that the operation is quite magical. I believe that this is probably one of the most difficult things to overcome, because the man in the mill who can't see the contactor go in and see something visually happening is a little bit mystified by tubes that work entirely electrically.

However, these factors are becoming a lot less troublesome, because there are always some very good radio men around, and they will probably find their place in mills. They are certainly creeping into other industries, and I believe that in the steel mills the same thing will happen.

ADVERTISING MATTER REMOVED

LONG RECOGNIZED where special flatness of sheet and strip is required, the Voss Ungerer Leveler has recently become a production machine. Performance records at greatly increased operating speeds have proven the soundness of the adjustable back-up roller design characterizing all Voss levelers.

Employing a multiplicity of narrow back-up rollers, this system of support prevents displacement of the leveling rolls in operation and provides a method of flexing the bottom rolls for localized flattening of the material. Overall roll support permits the use of smaller rolls, assuring positive deformation of the metal.

THE VOSS UNGERER LEVELER IS BUILT AND SOLD BY EDWARD W. VOSS UNDER UNITED STATES AND CANADIAN PATENTS

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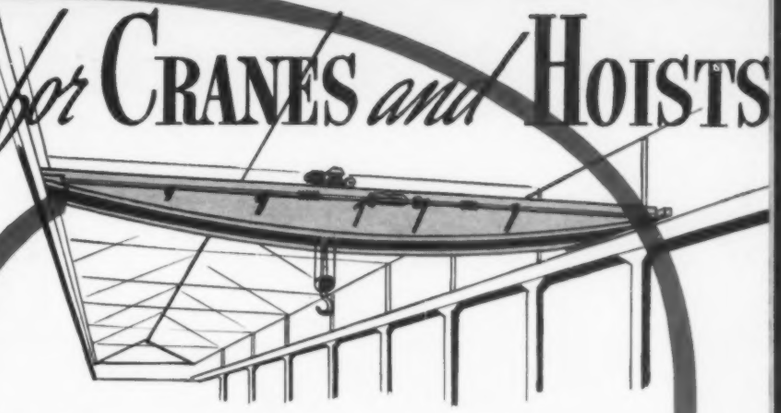
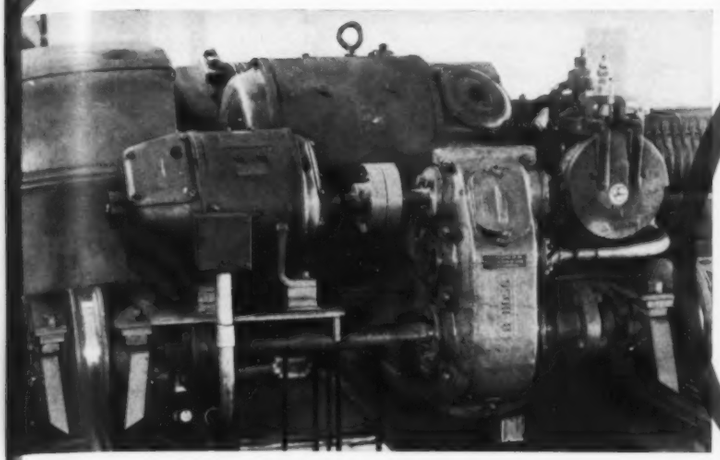
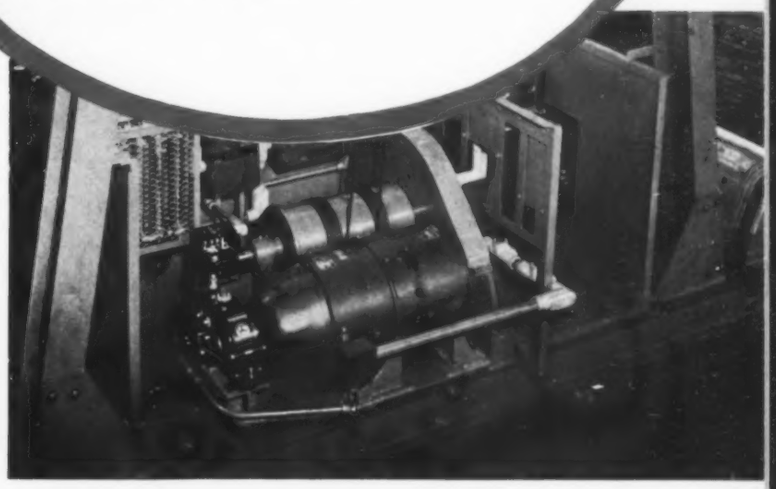
RELIANCE MOTORS *for* CRANES *and* HOISTS



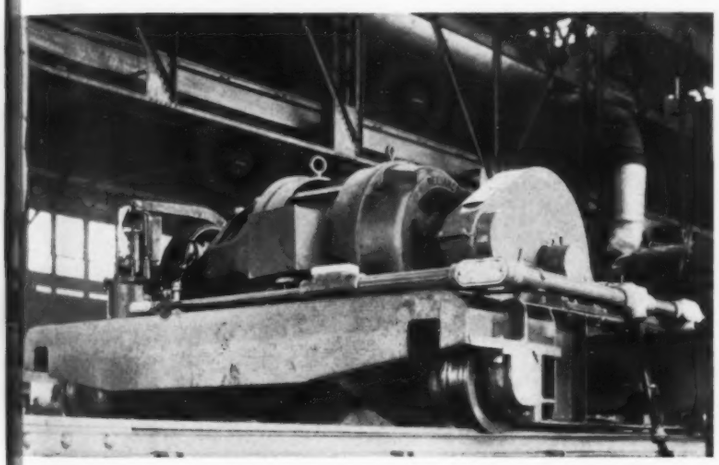
Steel for Strength. **The Reliance all-steel frame and foot construction provides the groundwork for withstanding the strains of frequent starting, reversing, and quick stopping. . . . Shafts made of specially-worked 45-carbon steel have a fine record in heavy-duty service.**



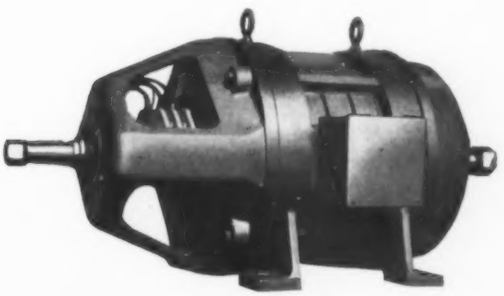
These d-c. general-purpose Reliance Crane Motors with full automatic control operate a 5-ton Whiting Crane.



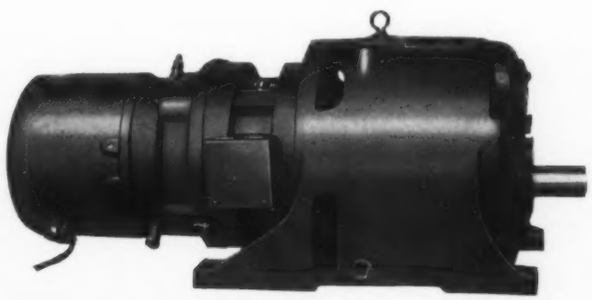
A 7½-hp. D-c. Reliance Gearmotor helped to simplify the design of this Cleveland Cleaning-house Crane. Operators handle bundles of rod fast with this equipment and give motors a real test.



The hoist of this Cleveland Crane is used to handle sheet steel and dies for automobile bodies. It is equipped with a 60-hp. Reliance Wound-rotor Crane Motor.



Crane-type Reliance Wound-rotor Motor; ball bearings, tapered shaft extensions.



Disc-brake gearmotor with a special-torque a-c. squirrel-cage motor unit. Provides a compact, rugged drive for hoists.

RELIANCE ELECTRIC & ENGINEERING CO., 1087 IVANHOE ROAD, CLEVELAND, OHIO

Birmingham, Boston, Buffalo, Chicago, Cincinnati, Detroit, Greenville (S. C.), Los Angeles, New York, Philadelphia, Pittsburgh, Portland (Ore.), St. Louis, San Francisco, Syracuse (N. Y.) and other principal cities.

RELIANCE A-C D-C MOTORS

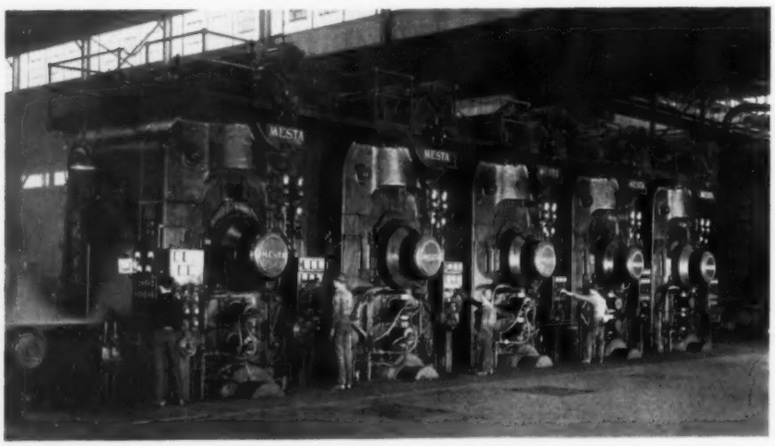
IRVIN WORKS INCREASES TIN PLATE CAPACITY WITH NEW INSTALLATIONS

▲ Carnegie-Illinois Steel Corporation is proceeding with plans for an increase in tin plate capacity at the Irvin Works. The contract for a five-stand 48 in., 4-high cold reduction mill, which will mark the first major extension of the Irvin Works since the plant was finished, was awarded to the Mesta Machine Company. In addition, Mesta was awarded a contract for twin 48 in., 4-high temper pass mills.

The new mills will be of the latest design, based on long experience gained in this field. When the Irvin Works was built in 1938, Mesta installed the hot rolling equipment consisting of ten stands of 4-high mills and the cold rolling mills. The latter included a 42 in. five-stand tandem mill, indicating the new installation will be capable of producing wider plates for tinning.

The program at Irvin includes processing equipment, but orders for this machinery have not yet been placed. Likewise, processing and finishing equipment planned for the corporation's Gary sheet and tin division have not yet been purchased.

Tin plate facilities at Irvin Works, as exemplified in the illustration, will be augmented by the new installations.



NEW PAD REDUCES ILL EFFECTS OF VIBRATION

▲ To offset the injurious effects of vibration on carbon brushes, National Carbon Company, Inc., is prepared to supply brushes with a resilient pressure pad secured to the holder end at the point of contact with the pressure finger. The use of these pads, where vibration of great severity is encountered, materially reduces and may even eliminate such destructive effects as chipping and cracking of brushes, wear on the holder end of the brush and wear of the pressure finger tip.

The resilient material used for these pads is very durable. Within the

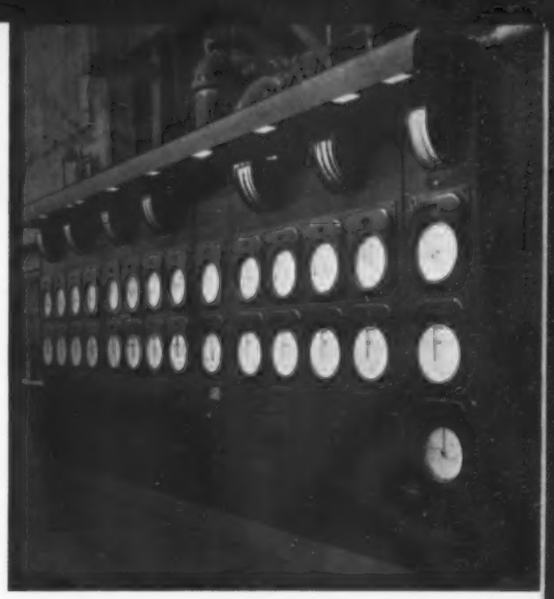
range of temperature normally encountered on electrical equipment the pad will retain its resiliency throughout the life of the brush. The form of the pad and its exact location on the brush are dependent on the shape and dimensions of the pressure finger and the location of its contact with the brush. The style shown in the illustration is adapted to a wide range of brush holder designs.

NEW LIGHTING UNIT FOR BOILER CONTROL BOARDS

▲ Development of an improved method of lighting boiler control boards that has many practical advantages over the methods used in the past is announced by the Hays Corporation. The new system consists of adding a top hood section to the control board and flushing Holophane "Controlens" units in the hood. The hood helps to keep dust off of the face of the board and adds materially to the appearance of the board. The

units are made dust tight by cementing in place in the steel housing and relamping from above by removing the flanged top. The light from the asymmetric lighting unit is directed vertically over the face of the board at such an angle that the specular reflection from the glass meter faces will not enter the observer's eyes and at the same time, the shadows on the meter faces (caused by interference of the meter case) will be a minimum. The worst shadow condition will be at the bottom of the board where there are no meters. At a point 3 ft. above the floor the shadow will be only 1 in. long for a meter having its scale ½ in. back of the metal case. The wide spread of light in the horizontal position gives excellent diffusion due to overlapping of light distribution.

Each Holophane unit uses two 6½ in. "Controlens" with a standard 100 watt lamp. One double unit is used per section which is equivalent to 18 in. spacing. The size of the opening in the hood to receive the unit is 8⅜ in. by 14 in., which allows a 3/16 in. clearance all around the unit. The hood should be 5¾ in. deep which will allow the unit to project approximately ½ in. above the hood to insure a dust tight fit to the relamping cover. The units are furnished with ½ and ¾ in. knockouts in each end which simplifies wiring inside the hood.



The new system of lighting consists of adding a top hood section to the control board.

15 ton-75'-0" span Cleveland all-welded crane with cab attached to trolley

CHOOSE THE CRANE THAT FITS THE JOB

There is no standard crane suitable for every requirement. Nearly every job has its peculiarities requiring a crane tailor-made to exactly fit the need.

Cleveland has had 40 years experience in all types of cranes — engineering and building them to meet the customer's requirements precisely.

Whatever your problem is we are in a position to work with you and will be glad to co-operate in every way. A call will bring our engineer— no obligation, of course.

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES

ALL-WELDED OVERHEAD TRAVELING CRANES

Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

REPUBLIC BLOWS IN NEW THOUSAND TON FURNACE

▲ Republic Steel Corporation's fourth blast furnace of a thousand, or more, ton capacity, was blown-in at Cleveland recently. Completion of this furnace gives the corporation two 1000-ton furnaces in Cleveland, a 1200-ton furnace in Warren, the largest in the world, and a 1000-ton furnace in Youngstown, out of nine blast furnaces in these three plants.

Work on the Cleveland furnace was started in March and its capacity has been increased from 550 to 1000 tons. The new furnace is 105 ft. high.

Blast furnace improvements have also been completed in both Birmingham and Youngstown. In the southern city the blast furnace plant capacity was increased by 35,000 tons a year and in Youngstown one of the furnaces was relined and general improvements were made.

MEETING COMMEMORATES ANNIVERSARY OF PATENT

▲ A meeting, which was attended by thirty-five sales representatives of the

Edwin L. Wiegand Company, from all parts of the United States and Canada, commemorated the 25th anniversary of the manufacture of the first "Chromalox" heating unit. Twenty-five years ago the first patent was issued on this heating unit, and during the following years the company has grown to be the largest concern devoting its facilities entirely to designing and manufacturing electrical heating units and equipment.

BEARING FIRM RAISES PRODUCTION CAPACITY

▲ The No. 2 plant of SKF Industries, Inc., will materially increase capacity in the production of more than 6000 types and sizes of ball and roller bearings. The one-story, saw-tooth, daylight type building contains 226,000 sq. ft. of floor space on a plot of 15 acres of beautifully-landscaped lawns, and will be devoted exclusively to the manufacture of anti-friction bearings.

Executive, sales, and sales engineering offices will remain at plant No. 1, site of the old Hess-Bright Manufacturing Company which was founded in 1904. Here, wing after wing has been added until practically all of the available manufacturing space has been utilized.

NEW LITERATURE

▲ Link-Belt Company has published a new catalogue on their complete line of flexible couplings. The book contains price and dimensional data on types A, B, and RC couplings, together with information on revolving and stationary casings for the RC type. The most recent addition to the line, a horizontally-split aluminum casing, is described fully. Simple selection tables and instructions for installation and lubrication make the book a valuable addition to the power transmission engineer's library.

A copy of this book may be obtained by writing to the Link-Belt Company, 307 North Michigan Avenue, Chicago, Illinois, and requesting Catalogue No. 1845.

▲ Okonite Company has completed a very interesting book dealing with research on insulation. The various steps in the development of a new insulation or protective sheath is illustrated by photographs, and concise editorial description.

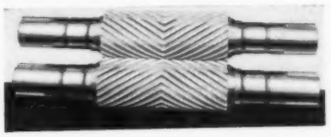
Copies of the book may be obtained by writing to the Okonite Company, Passaic, New Jersey.

▲ Koppers Company describes the Koppers semi-continuous light oil refining process in a bulletin issued by the Engineering and Construction Division of that company. Covering in detail a light oil refining installation at the Wheeling Steel Corporation, this book tells how the installation takes crude light oil from the existing stripping-plant and refines it into forerunnings, motor fuel, pure benzol, pure toluol, pure xylol and solvent naphtha.

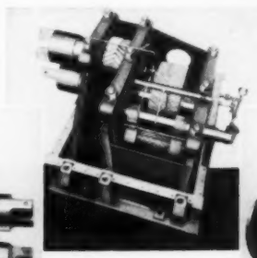
By-product plant men and other interested officials may secure copies of this book by writing to the Engineering and Construction Division of the Koppers Company, Pittsburgh, Pennsylvania.

FARREL GEAR DRIVES *and* PINION STANDS

Adaptable to Individual Operating Conditions

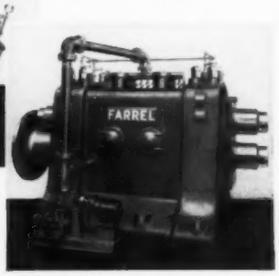


Below and Center—Two views of Double Reduction Drive and integral 20-inch Pinion Stand with welded steel case.



Above—Farrel-Sykes continuous tooth herringbone rolling mill pinions are precision generated for smooth, quiet operation.

Right—4,000 HP Pinion Stand for four-high reversing cold strip finishing mill.



Farrel Heavy Duty Rolling Mill Drives and Pinion Stands are adaptable by design and construction to individual conditions of operation. For example, the beds may be cast steel or Meehanite or welded steel construction. Dependent upon load conditions and the requirements for rigidity a double-walled or single-walled deep base may be used. Bearings may be either plain babbit-lined steel cartridges or any approved make of anti-friction bearing.

While gears and pinions are usually continuous-tooth herringbone, accurately generated by the Farrel-Sykes process, either single helical or a combination of single and double helical gears can be furnished. As conditions demand, lubrication may be by dip and splash system, by pump built into the unit and driven by one of the shafts, or by separate lubrication system.

The high precision with which Farrel Mill Drives and Pinion Stands are made assures smooth, quiet operation, and their rugged construction enables them to withstand the stresses, shocks and wear incident to the high speeds and heavy loads of modern mill practice.

When you have a gear problem call in a Farrel gear engineer for consultation.

FARREL

FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN.
New York • Buffalo • Pittsburgh • Akron • Chicago • Los Angeles

ITEMS OF INTEREST

Martin J. Conway, who has been fuel engineer for Lukens Steel Company, Coatesville, Pennsylvania, since August, 1926, has been appointed special engineer for the petroleum industry. Mr. Conway was born in England and was graduated from Oxford University in 1914 with degrees in mechanical engineering and chemical engineering.

From 1914 to 1920, except for the war years when his activities were directed toward government work, Mr. Conway was in charge of tar distillation and by-products operation at the Blaenavon Iron and Coal Company, Ltd., Blaenavon, Monmouthshire, England. Concurrently, Mr. Conway was a consulting engineer handling the design of distillation plants for Fraser and Company, Dagenham, Essex, England.

In 1920, Mr. Conway joined the Pittsburgh Crucible Steel Company, Midland, Pennsylvania, as fuel engineer. In 1923, he joined the Steubenville, Ohio, plant of the Wheeling Steel Corporation, in a similar capacity. From 1926 until recently, Mr. Conway has been fuel engineer for Lukens Steel Company in charge of producer gas plants, boiler plant operation, furnace and fuel efficiency, distribution and engineering work of special interest dealing with both fuel and metallurgy.

Mr. Conway is an active member of the Association of Iron and Steel Engineers, and has served in various capacities on the board of directors of the Association.

Harold P. Ingram was appointed general superintendent of the roll and machine plant of the Carnegie-Illinois Steel Corporation, Canton, Ohio. Mr. Ingram, who until the present appointment was superintendent of the corporation's maintenance department at the Homestead Works, was born at Homestead, Pennsylvania, in 1898. He attended high school in Homestead and later attended the Carnegie Institute of Technology. He began his industrial career in the engineering department of Westinghouse Electric and Manufacturing Company at East Pittsburgh in May, 1913. In November, 1915, Mr. Ingram became affiliated with the Carnegie-Illinois Steel Corporation as an apprentice in the roll department of the Homestead Works. From January, 1920, until February, 1928, he was employed as a draftsman.

In February, 1928, he was appointed superintendent of the roll department at the Homestead plant. Mr. Ingram has been superintendent of the maintenance department at Homestead since August 1, 1938.

Warren W. Scherer has been appointed superintendent of maintenance at the Homestead Works of the Carnegie-Illinois Steel Corporation. Mr. Scherer has been associated with the corporation since 1920, serving in the maintenance department at the Clairton Works until 1937. He was assistant superintendent of construction at Irvin Works, later becoming superintendent of maintenance, and subsequently superintendent of industrial relations.

Carnegie-Illinois Steel Corporation has made the following promotions in the operating department of the Homestead Steel Works:

Robert Urquhart, employed at Homestead since 1914, was appointed assistant general superintendent in charge of operations;

Walter F. Nicoden succeeded Mr. Urquhart as superintendent of the open hearth departments;

Robert O. Thomas, formerly assistant to chief inspector, was named chief metallurgist;

A. B. Steigerwalt has been appointed superintendent of production shops;

Myron W. Lewis was named plant industrial engineer;

W. C. Hogg was appointed assistant superintendent of open hearth departments;

A. L. Adams has been made superintendent of open hearths No. 1 and No. 2 and foundry, succeeding Mr. Hogg.

John W. Alden has joined the Steel and Tube Division of the Timken Roller Bearing Company as mill metallurgist. Mr. Alden is a graduate of Oberlin Academy and Columbia University, and was employed as a metallurgist by the United Steel Company, Central Alloy Steel Corporation and Republic Steel Corporation before coming to the Timken Roller Bearing Company.

MARTIN J. CONWAY

HAROLD P. INGRAM

WARREN W. SCHERER

H. G. COFFEY

H. G. Coffey
has been advanced to the post of manager of sales for the Aetna-Standard Engineering Company, Youngstown, Ohio.

Mr. Coffey was formerly assistant manager of sales for this company. He joined the Aetna Foundry and Machine Company, the predecessor of the Aetna-Standard Engineering Company, in a sales capacity about 15 years ago, after service with the Youngstown Sheet and Tube Company.

Frank McDanel
succeeds George M. Hunter, retired, as vice-president in charge of manufacturing operations for the American Bridge Company, Pittsburgh, Pennsylvania. Mr. McDanel, a native of New Brighton, Pennsylvania, has served continuously at the Ambridge plant for 36 years. Since his first assignment as a helper, he has occupied various plant supervisory positions. He was appointed plant superintendent in 1923 and continued in that capacity until his recent advancement.

John Shillinglaw
has been appointed purchasing agent for the Allegheny-Ludlum Steel Corporation, Watervliet, New York. Mr. Shillinglaw has been in the employ of the company for about 20 years, during which time he was auditor of Ludlum Steel Company, and since the merger, has been in the accounting department of the Allegheny-Ludlum Steel Corporation.

Carl Roeder,
field installation supervisor for the Farval Corporation, Cleveland, Ohio, recently returned from England. Mr. Roeder had been in England for two years superintending the installation of Farval lubricating equipment in John Summers and Sons hot strip mill at Chester, England, and in other English plants.

James E. Turner
was appointed purchasing agent for the Atlantic Steel Company, Atlanta, Georgia. Mr. Turner is a native of Alabama, and is a graduate of Alabama Polytechnic Institute at Auburn. He was formerly associated with the Allis-Chalmers Manufacturing Company and the Pioneer Manufacturing Company.

Fred C. Frame
was named to Warren W. Scherer's former position as superintendent of industrial relations at the Carnegie-Illinois Steel Corporation's Irvin Works. Mr. Frame, a graduate of the University of Pennsylvania, was plant industrial engineer at the Wood Works of Carnegie-Illinois Steel Corporation, McKeesport, Pennsylvania, from 1936 to February, 1938. He has been plant director of training at Irvin Works since June 1, 1938.

PHOTOGRAPH COURTESY THE ANSLER-MORTON COMPANY
They "see" what's going on in the soaking pits—
HAYS COMBUSTION INSTRUMENTS AND CONTROL
INDICATING AND RECORDING INSTRUMENTS ACCURATELY DEPICT
GAS PRESSURE, FURNACE PRESSURE, AIR FLOW
In the above installation a Hays "OT" Recorder (pane at the left) accurately records the gas pressure for every minute of the day and night. An Air Flow indicator (upper panel) shows continuously the air volume and flashes a warning signal when it reaches 25% of the load or lower. At the same time a Hays "D" Gage indicates the pressure inside the furnace. Thus is guesswork and uncertainty eliminated.
Hays Combustion Instruments have set the standard for accuracy, dependability and stamina for 38 years. They are as well known in the steel mills and power plants of the country as a monkey wrench. They can be designed to meet practically any requirement concerning indicating, recording and controlling of combustion conditions. Hays Engineer-representatives are located in all the principal cities to help industry in the solution of its combustion problems. They will be glad to serve you. Write to 955 Eighth Ave., Michigan City, Indiana.
The COMPLETE HAYS LINE
CO2 Recorders
Pointer Type Draft Gages
Portable Combustion Testing Instruments
Combustion Control
The HAYS CORPORATION
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MICHIGAN CITY, INDIANA, U.S.A.